Project Formation Research on
High-efficiency Coal Utilization Systems

Feasibility Study on An Urban-located, Eco-friendly, High-efficiency Coal-fired Power Project in India

Sponsored by

New Energy and Industrial Technology Development Organization (NEDO)

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Prepared by

Japan Coal Energy Center

Electric Power Development Co., Ltd.

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Executive Summary

Government of India introduced a new environmental norms for new and all existing thermal power station (TPS) in December 2015. Power sector's current top concern is how to address the new norms for achieving higher thermal efficiency of TPS and mitigating environmental impacts. In this point of view, NTPC's Badarpur TPS has been selected as a model site, where feasibility is studied on adopting the latest USC technologies to the existing TPS along with the comprehensive environmental measures.

In the study, empowering, technical specification, construction schedule, economic feasibility GHG reduction and mitigation of environmental impact by replacement have been considered. This Japanese technologies based study will provide a good example for future new power project as well as making concrete replacement plan

Study Items are conceptual design, O&M plan, construction cost, financial analysis, environmental and social considerations, business plan, project plan, ash utilization, CO_2 reduction, project structure and steering committee. Site survey and technical meetings with Badarpur TPS have been conducted to complete above study items.

Size of new USC unit is 660 MW, its steam pressure, main steam temperature and reheat steam temperature are 26.48 MPa, 600 degC and 600 degC, respectively. In a turbine island, optimization of steam flow on turbine blade, long turbine blade at the last stage, and high performance seal technology are adopted.

As latest environmental technologies, low-low temperature ESP, SCR and wet limestone-gypsum FGD are selected. By adopting these new technologies, emission of new plant is kept low enough, such as 30 mg/m^3N SPM, 100 mg/m^3N NOx, 100 mg/m^3N SO_2. Diffusion simulation of these pollutant materials is also conducted and confirmed that surrounded ambient environment is kept clean. Plant water consumption is lower than 2.5 m^3/MWh to meet new norms. Plan based on Japanese experience is proposed. Capital cost of new plant is estimated as 1,210 USD/kW, (without environmental facilities: 1,049 USD/kW） with construction period of 5 years.

CO_2 reduction effect was studied by comparing several baseline of efficiency guideline (SC), emission coefficient of grid, PAT target and current TPS emission. Annual emission reduction was 20% from each baseline. Ash demand in Delhi region is found to be very high in construction industries such as cement and blocks. As for future viding, participation by the consortium of Japanese manufactures are most considerable.

Because of the postpone of the replacement implementation at Badarpur TPS, only 1st steering committee has been held and the main purpose of this FS is changed as "to apply this result for future new project / replacement project". In view of the comment by NTPC board member, this feasibility study was thought to show a good outcome for future opportunities.

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1.1 Background

Government of India introduced a new environmental norms for new and all existing thermal power station (TPS) in December 2015. Power sector's current top concern is how to address the new norms for achieving higher thermal efficiency of TPS and mitigating environmental impacts. In this point of view, NTPC's Badarpur TPS has been selected as a model site, where feasibility is studied on adopting the latest USC technologies to the existing TPS along with the comprehensive environmental measures.

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1.2 Purpose of Study

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1.3 Study Fields

(1) Energy Trend in India

1) Power Sector

Energy politics, power development plan and grid plan surrounding Delhi capital have been studied through the interview with concerned officials in MOP、CEA、NTPC

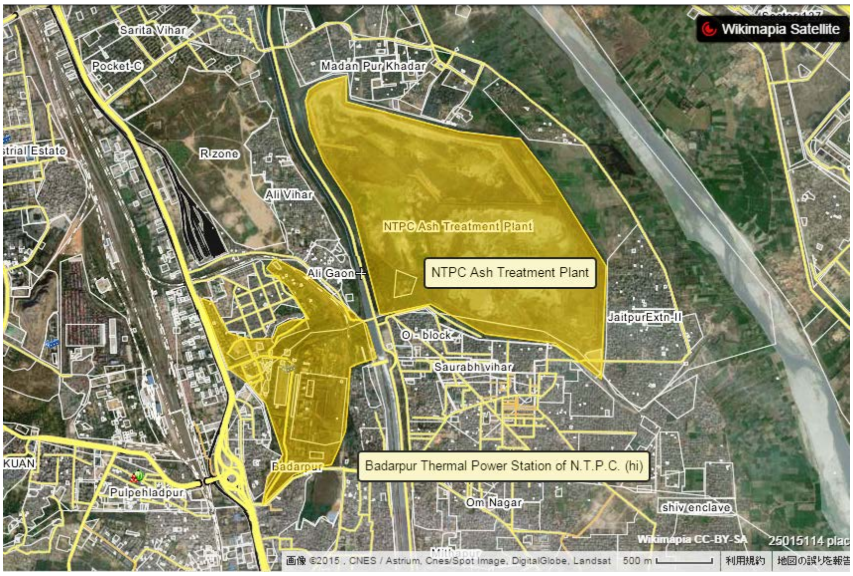
(2) Site Survey

1) Badarpur Thermal Power Station

Badarpur thermal power station was selected as one example of replacement of aged sub-critical thermal power plant to latest USC (Ultra Super Critical) through the discussion with NTPC. Figure 1.3-1 and Figure 1.3-2 show current plant and study area of Badarpur TPS. Plant area, coal yard and ash dyke with surrounding condition such as climate in Delhi, water supply, fuel supply, switching yard, construction field, equipment installation route, air regulation and surrounding residential area were studied.

Source: Panoramio

Figure 1.3-1　Badarpur Thermal Power Station



Source: Wikimapia

Figure 1.3-2　Study Area

2)　Identification of the Construction Site

Construction area is studied based on it land condition, current plant area, coal yard and other factors.

3)　Fuel Supply Planning

Both imported and domestic coal are to be considered for the fuel used in the new plant. By replacing new USC with empowering its generation, coal consumption is estimated to be increased. Current domestic coal linkage, new linkage and possibility of imported coal is also studied.

(3) Conceptual Design of New Generating Units

1) Conceptual Design of New Generating Units

Design condition such as construction area and fuel properties is studied for high efficiency coal thermal plant equipment. Current facilities of coal unloading, switching yard, ash dyke will be used to minimize its construction cost.

Latest Clean Coal Technologies (CCT) by Japanese manufacturers will be considered to design new plant. Either of 2 × 660 MW, 2 × 800 MW, 3 × 660 MW will be selected for detailed study.

2) Optimal O&M Planning

Operation & Maintenance for new plant will be also studied by enhancing current NTPC O&M procedures.

3) Project Cost Estimation

Rough estimation no construction cost will be studied.

4) Economic Financial Analysis

According to the construction cost/O&M cost, its project cost will be estimated. Its financial option by Japanese public finance scheme such as JBIC buyer's credit, Yen Loan by JICA will be studied by comparing with private bank loan.

5) Environmental Impact

Analysis based on the diffusion simulation techniques for pollutant matters in flue gas will be studied and compared with the guideline of air protection Act.

(4) Project Plan

1) Project Plan

FIIR of the project will be estimated based on the result of Economical/Financial Analysis.

2) Ash Utilization

Ash discharge amount from new plat will be increased and its utilization is an essential issue to be addressed.

3) CO_2 Mitigation Effect

CO_2 emission by new plant will be calculated and compared with its current data to clarify the potential of CCT for the replacement.

(5) Project Structures

1) Project Structures

In case that this feasibility study materialized, international competitive tender by NTPC is conducted. To participate this tender, consortium by Japanese manufacturers will be considered.

(6) Others

1) Steering Committee

Steering committee Steering committee members from CEA (1), NTPC (4) from India side, Study team (JPOWER (2), Kyusyu (2) and JCOAL (1)) from Japanese side are nominated to discuss the progress of the studies under supervision by both governments.

2) Report

Study report written in Japanese and English will be submitted to NEDO and relevant organization in India.

1.4 Period of Study

This feasibility study has been conducted from September 18, 2015 to June 30, 2016.

1.5 Study Schedule

Study Schedule is shown in Table 1.5-1.

Table 1.5-1 Study Schedule

Study Item	2Q	3Q FY2015			4Q, FY2015			1Q FY2016		
	Sept	**Oct.**	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apl.**	**May**	**Jun.**
1. Power Sector Situation			━	━	→					
2. Confirmation of the Current Plant Condition			━	━	━	━	→			
3. Identification of the Construction Site			━	━	━	━	━	→		
4. Fuel Supply Planning			━	━	→					
5. Conceptual Design of New Generating Units			━	━	━	━	━	━	→	
6. Optimal O&M Planning			━	━	━	→				
7. Project Cost Estimation			━	━	━	━	━	━	→	
8. Economic Financial Analysis				━	━	━	━	━	→	
9. Environmental impact				━	━	━	━	━	→	
10. Project plan				━	━	━	━	━	→	
11. Ash Utilization			━	━	━	→				
12. CO^2 mitigation				━	━	→				
13. Project structure				━	━	━	━	━	━	→
14. Steering committee		━	━	━	━	━	━	━	━	→
15. report					━	━	━	━	━	→

1.6 Study Team Structure

This study has been conducted by Electric Power Development Co., Ltd, Kyusyu Electric Power Co., Ltd. and Japan Coal Energy Center (JCOAL). Its study framework is shown in Figure 1.6-1. The feasibility study was conducted under the budget and supervision by NEDO.

NEDO

JCOAL	J-POWER	Kyushu Electric Power
Study Item:	Study Item:	Study Item:
1. Study on Power Sector	1. Identification of the site	1. Specification of new plant
2. Fuel Supply Plan	2. Specification of new plant	2. Design of Turbine/Generator
3. Environmental measures trend	3. Design of oiler, BOP	3. O&M planning
4. CO_2 reduction effect	4. Design of Environmental equipments	4. Report
5. Collection of local data	5. Construction cost	
6. Ash Utilization	6. Study on Environmental impact	
7. Steering committee	7. Economic financial analysis	
8. Report	8. Report	

Figure 1.6-1 Study Framework

Work Item of each organization is;

J-POWER: identification of the site, specification of new plant, design of oiler, BOP, design of environmental equipment's, construction cost, study on environmental impact, economic financial analysis

Kyushu: specification of new plant, design of turbine/generator, O&M planning

JCOAL: study on power sector, fuel supply plan, environmental measures trend, CO_2 reduction effect, Collection of local data, Ash Utilization, Steering committee.

1.7 Counterpart

The counterpart of the study was NTPC, the largest power generation company in India which has 17 thermal power station and 3 joint venture generation companies. Figure 1.7-1 shows a relevant organization structure in India power sector including NTPC and CEA (Central Electricity Authority).

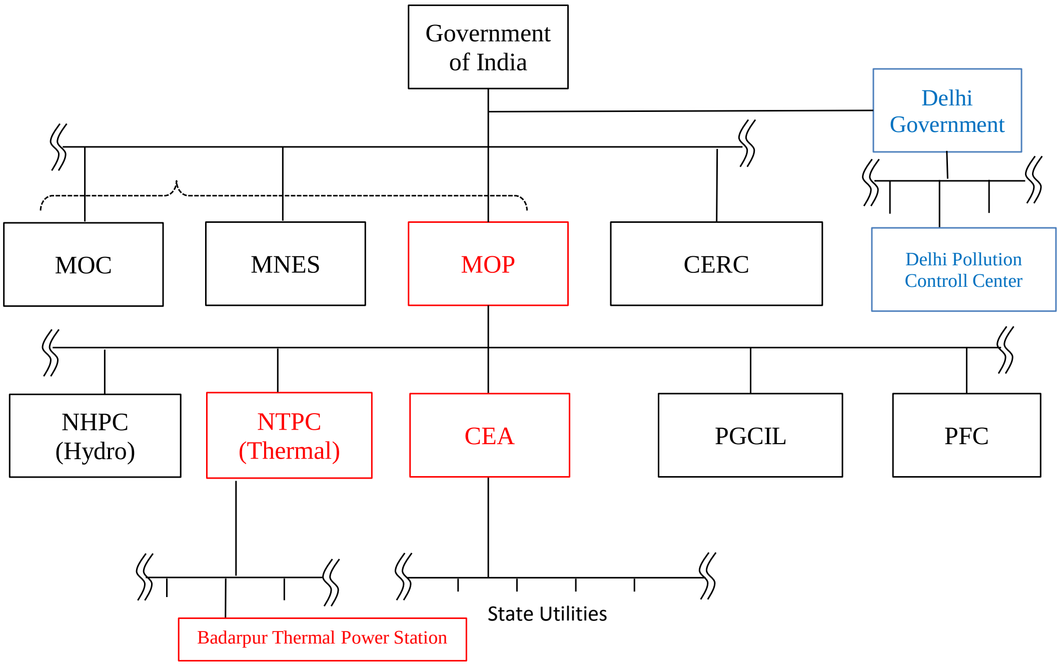


Figure 1.7-1 Structure of Power Sector and Position of Counterpart

1.8 Study team members

Table 1.8-1 shows a member list of the study team who has joined this feasibility study.

Table 1.8-1 Study Team Members

No	M/F	Organization	
1	Mr.	Electric Power Development Co.,Ltd. (JPOWER)	SAKURAI MOTOHISA
2	Mr.		KOIZUMI NOBUCHIKA
3	Mr.		TOYAMA TOSHIAKI
4	Mr.		YAMADA KAZUYUKI
5	Mr.		MEGURO KOICHI
6	Mr.		KOBAYASHI HIRONAO
7	Mr.		TORIYAMA SOICHI
8	Mr.		HIRAHARA TETSUYA
9	Mr.		ARAI HIROMICHI
10	Mr.	Kyusyu Electric Power Co., Inc.	MITSUNAGA YOSHIFUMI
11	Mr.		TSUKIMOTO KIYOTAKA
12	Mr.		GOMI SHUNSUKE
13	Mr.		INOUE MASATOSHI
14	Mr.		EZAKI HIROFUMI
15	Mr.	Japan Coal Energy Oenter (JCOAL)	KAWAMURA YASUSHI
16	Mr.		MURAKAMI KAZUYUKI
17	Mr.		OZAWA MASAHIRO
18	Mr.		KUBOTA TOMIO
19	Mr.		YAMADA FUMIKO
20	Mr.		YAMADA TOSHIHIKO
21	Mr.		KOGA HANJI

CHAPTER 2

CURRENT SITUATION IN INDIA POWER SECTOR

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CURRENT SITUATION IN INDIA POWER SECTOR

2.1 Capacity addition plan

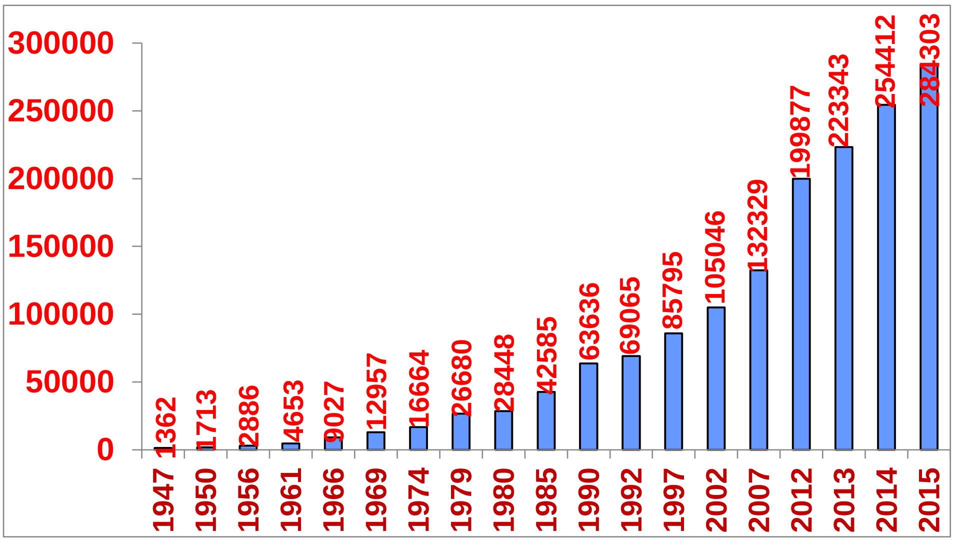
Table 2.1-1 Shows energy wise capacity in India as of April, 2016. Total capacity was 302 GW and its 61.4% is of Coal thermal.

Table 2.1-1 Energy wise Capacity (as of April, 2016)

	Hydro	Thermal				Nuclear	New & Renewable Energy	Total
		Coal	Gas	Diesel	total			
GW	42.783	185.992	24.508	0.919	211.42	5.78	42.849	302.833
%	14.1	61.4	8.1	0.3	69.8	1.9	14.1	100.0

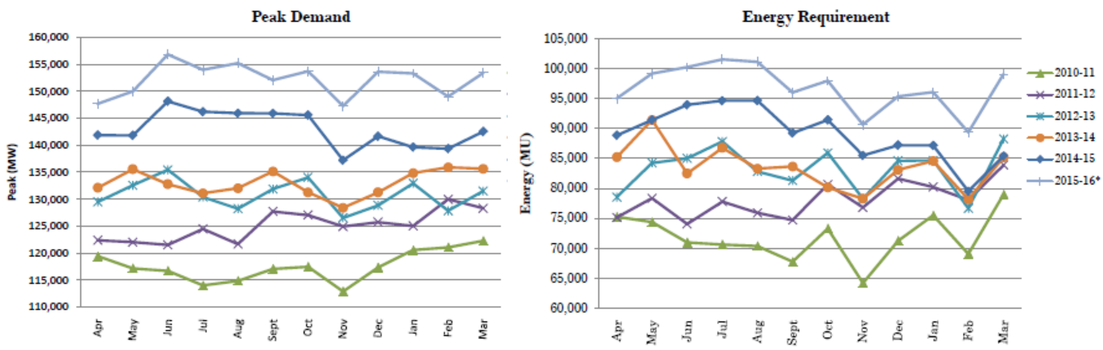
Source: Monthly Report, May 2016, CEA

Figure 2.1-1 shows a change in total capacity of Indi. As India's economic growth, drastic capacity addition has been implemented especially, after 2000.



Source: CCT transfer, information and knowledge exchange programme, CEA, 2015

Figure 2.1-1 Change in Total Capacity of India



Source: Load Generation Balance Report 2015-2016, MOP

Figure 2.1-2 Monthly Trend of Peak Demand (left) and Power Demand (right)

Figure 2.1-2 shows a monthly trend of Peak Demand (left) and Power Demand (right).

According to state/region wise supply/demand gap (Table 2.1-2), both peak capacity and power demand of North and South region is high, supply/demand gap of North region is still high. Supply/demand gap of whole India is about 2%, much improved than that of 10 years back.

Table 2.1-2 State/region wise supply/demand gap

Anticipated All India Power Supply Position for the year 2015-16

State / Region	Energy				Peak			
	Requirement	Availability	Surplus(+)/ Deficit (-)		Demand	Met	Surplus(+)/ Deficit (-)	
	(MU)	(MU)	(MU)	(%)	(MW)	(MW)	(MW)	(%)
Northern	355,794	354,540	-1,254	-0.4	54,329	54,137	-192	-0.4
Western	353,068	364,826	11,758	3.3	48,479	50,254	1,775	3.7
Southern	313,248	277,979	-35,269	-11.3	43,630	35,011	-8,619	-19.8
Eastern	124,610	127,066	2,455	2.0	18,507	19,358	851	4.6
North-Eastern	15,703	13,934	-1,768	-11.3	2,650	2,544	-106	-4.0
All India	1,162,423	1,138,346	-24,077	-2.1	156,862	152,754	-4,108	-2.6

Source: Load Generation Balance Report 2015-2016, MOP

2.1.1 Power situation in Delhi Capital Territory

To safeguard Delhi and its surrounding areas from electricity supply disruption during grid failure, Government has introduced “Islanding Scheme” in January 2013. These units would together generate about 4,200 MW and would be capable of meeting about 3,400 MW of load, during peak hours.

(1) Dadri- - Jajjhar- Pragati (part) Island (Peak load 2,315 MW)

(2) Bawana CCGT Island (Peak load 600 MW)

(3) BTPS-Pragati (part) Island (Peak load 500 MW)

(4) Rithala CCGT Island (Peak load 20 MW)

Badarpur TPS is operated as the member TPS in (iii) BTPS-Pragati (part) Island.

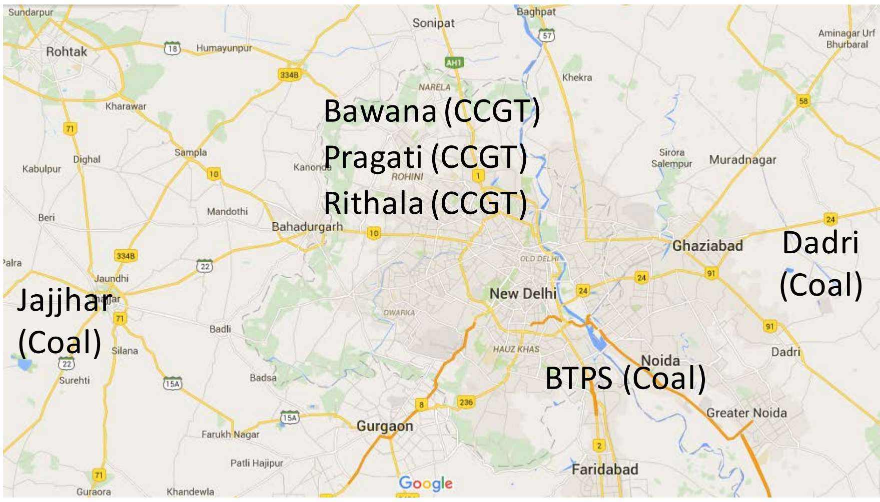


Figure 2.1-3 Delhi Islanding Scheme

2.1.2 Power demand forecast, long term power development plan

Table 2.1-3 shows an energy wise capacity trend in India. Current government show a proactive policy to introduce renewable energy to mitigate CO_2 emission, percentage of renewable is become nearly equal to coal in 2040.

Table 2.1-3 Energy wise capacity trend in India

		2000	2014	2020	2030	2040
Fossil fuels	(GW)	84	204	280	419	576
	(%)	74.3	70.6	64.2	56.2	53.5
Coal	(GW)	66	174	230	329	438
	(%)	58.4	60.2	52.8	44.1	40.7
Gas	(GW)	11	23	41	76	122
	(%)	9.7	8.0	9.4	10.2	11.3
Oil	(GW)	7	7	9	13	15
	(%)	6.2	2.4	2.1	1.7	1.4
Nuclear	(GW)	3	6	10	24	39
	(%)	2.7	2.1	2.3	3.2	3.6
Renewables	(GW)	27	79	147	304	462
	(%)	23.9	27.3	33.7	40.8	42.9
Total	(GW)	113	289	436	746	1076

Source: IEA World Energy Outlook Special Report "India Energy Outlook"

This forecast is based on the optimal case of the implementation of renewable project. Currently coal is a main stay in India energy sector by its abundance of domestic resources as base load energy. On the other hand, MOP start to consider the compensation of fluctuation by renewable energy such as wind and solar.

CHAPTER 3
FUEL SUPPLY PLAN AND ASH UTILIZATION FOR NEW PLANT

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In this chapter, study on fuel supply plan and ash utilization are described as the sample case of replacement by using the data of Badarpur TPS to latest USC.

3.1 Fuel supply plan

Annual coal consumption of new plant which capacity is 1,320 (2 x 660) MW, is assumed 580 million tonne per annual. Current coal linkage can cover 480 million tonne (Currently 420 million tonne) and another 100 million tonne is required to be added. Another issue is its fuel cost, especially transportation of coal by rail is found to be extremely high. To find a solution of above two points, hearing at relevant organization and concerned position in NTPC has been conducted (Table 3.1-1). As a results,

- ✓ Restructuring of linkage such as tapering, bridge linkage.
- ✓ 100 million tonne from NTPC captive block.
- ✓ Selective use of washed coal
- ✓ Upgraded lignite at Rajasthan by UBC process

are proposed. Further detailed study will be required at the implementation stage.

Table 3.1-1 Fuel supply plan and issues to be considered

➢ Proposal of fuel supply plan for new plant

1) Tapering linkage, Bridge linkage, reallocation of linkage, new linkage.
   Reduction of transportation cost by restructuring coal linkage, but need discussion at political level

2) NTPC Captive mines
   Reduction of coal cost directly by supplying approx. 1MTPA from NTPC captive mine.

3) Washed coal
   Upgrade of G12 to G10-8 grade is worth to be considered to reduce transportation cost. This means a reduction of transportation cost of ASH

4) Supply from Upgrade lignite by UBC process
   Reduction of ash contents, transportation cost, etc., UBC (Upgraded Brown Coal) technology is worth to be considered. Lignite at Rajasthan is most considerable.

3.2 Ash Utilization

Ash Utilization is one of common issue of coal fired power station in India. Ash pond area per MW and fly ash utilization plan is required for new power project. In this point of view, studies concerning current and new plant ash situation and demand have been conducted.

In the case that TPS is operated with full load of 705MW, discharged ash is 120,000 t/M. Current ash dispatch is 119% for cement and block application, which means current demand is 142,800 t/M (Figure 3.2-1). On the other hand, new plant requires 5.8 MTPA, which means discharged ash is expected to be 165,700 t/M. Only 22,900 t/M is accumulated in ash dyke.

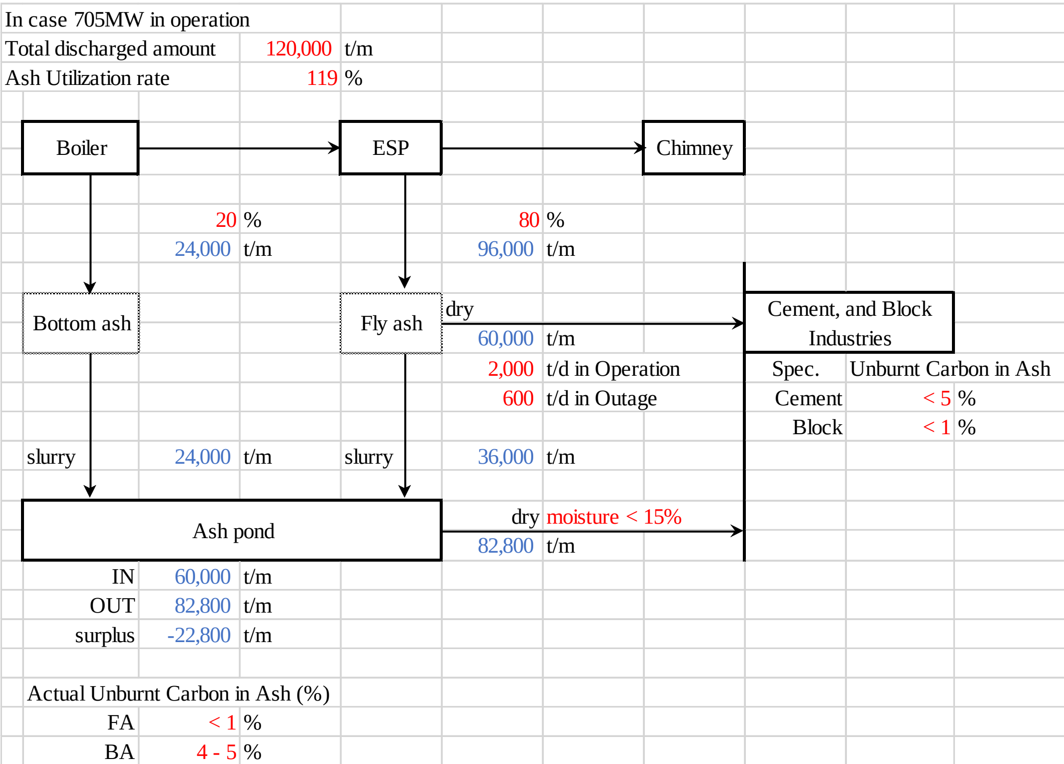

Figure 3.2-1 Ash discharge flow at Badarpur (@705 MW operation case)

Fly ash is mainly used as a component of cement, its utilization rare is around 40% out of 55% of total ash utilization. Cement demand is strongly depends on economy growth. Demand in NCR Delhi is high and is expected to continue another 20 years. As an example, construction of eastern peripheral road is required approx. 25,000,000 t of ash during coming 4 years. From the view point of users, fly ash has been purchased from FY 2006, which is a dominant factor to push up cement cost as well as transportation cost. Also low quality of ash causing coal quality is concerned.

CHAPTER 4

GENERAL DESCRIPTION OF POWER PLANT

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4.1 Selection of Construction Site

At early stage of our site survey, new 2 × 660 MW power generating units were planned on the main plant area, where the existing Unit 1 to Unit 5 nestle, for better utilization of the existing equipment as shown in Figure 4.1-2 as Plan-B. However, at later stage of the survey, we found some of the equipment, such as coal storage yard, rail way system and water intake facility, can be utilized with renovation and expansion for new 2 × 660 MW units. Further, it was considered a time-consuming scheme to mobilize and isolate some parts of the existing system, which may require additional work.

Therefore, it was concluded to build the major power generating facility on the plain ash pond area, rather than on the existing major equipment area, along with the renovated and enhanced railway system, coal storage system and water intake system staying on the current locations, as being Plan-A as shown in Figure 4.1-1 below.

Figure 4.1-1 Major Equipment Installed on Existing Ash Pond (PLAN-A)

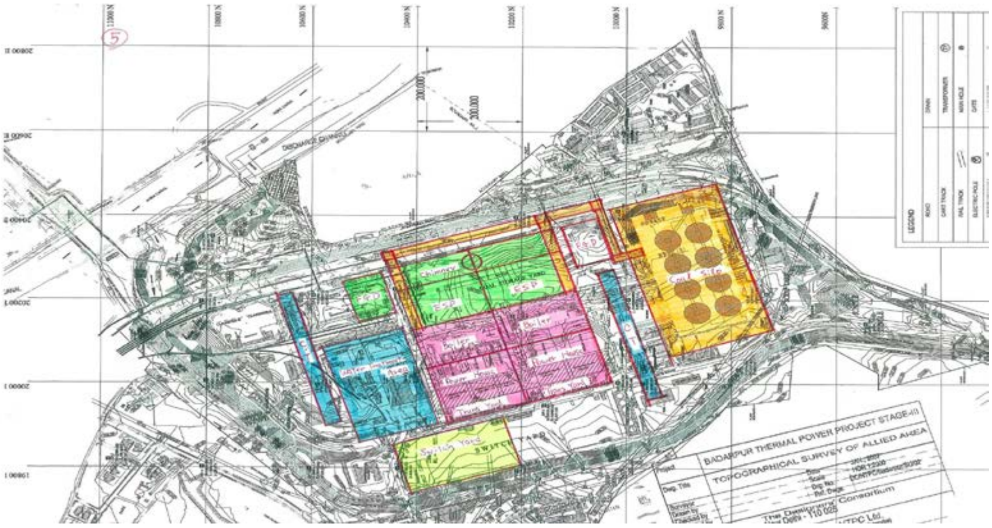

Figure 4.1-2 Major Equipment Installed on Existing Main Plant Area (PLAN-B)

4.2 General Configuration of Power Plant

Unit capacity of 660 MW coal fired power station, which realizes high efficiency by adopting higher steam temperature based on experienced and existing technology, is proposed, taking design coal specification and emission regulation of existing power station into consideration.

The power station consists of mainly;

- Boiler
- Steam turbine and generator
- Environmental protection system(De-SOx and dust collector)

Specification and performance of the power station is shown below.

4.3 General Features of Power Plant

4.3.1 Primary Fuel

Design coal is Indian domestic coal.

Assuming that location of power station is far from coal mine, in order to achieve high efficiency and Eco-friendly power station, washed coal is adopted as design coal.

Table 4.3-1 shows design coal specification.

Table 4.3-1 Design Coal Specification

ITEM		Design
Proximate analysis (Air dry)		
Inherent moisture	%	7.0
Volatile	%	23.0
Fixed carbon	%	31.0
Ash	%	39.0
HHV (as received)	kJ/kg	17,166
Ultimate analysis (as received)		
C	%	39.91
H	%	3.25
N	%	0.88
O	%	6.52
S	%	0.44
H_2O	%	12.00
Ash	%	37.00
HGI		60
Ash analysis		
SiO_2	%	62.0
$Al2O_3$	%	25.3
Fe_2O_3	%	5.6
CaO	%	1.68
MgO	%	1.11
Na2O	%	0.4
K_2O	%	1.85
TiO_2	%	1.38
P_2O_5	%	0.45
SO_3	%	0.25
Ash fusion temp. (reducing)		
Initial Deformation Temp.	°C	1,200
Fluid Temp.	°C	1,400

4.3.2 Applicable Emission Standards

Table 4.3-2 shows design emission standard of this study and that of India for comparison.

Table 4.3-2 Emission Standards

ITEM	Unit	India (before 2016, ≧ 500 MW)	India (COD after 2017)	Design
NOx	$mg/m^3N(6\%O_2)$	300	100	100
SOx	$mg/m^3N(6\%O_2)$	200	100	100
Dust	$mg/m^3N(6\%O_2)$	50	30	30

4.3.3 Boiler Type

Common used boilers in thermal power plants are categorized mainly in two types, one equipped with steam drum known as drum boiler and the other is without steam drum and generally known as once-through boiler. The drum boiler consists of steam drum, downcomers, water tubes and super heaters. As recirculation of drum water is due to difference of the specific gravity between saturated water in downcomers and mixture of saturated steam and saturated water in water tubes, therefore, such recirculation is only possible in subcritical boilers. Whereas once-through boiler mainly consists of small diameter tubes through which pressurized water from boiler feedwater pump passes through and converted into superheated steam. As the water evaporate while passing through tubes, therefore, recirculation process and its associated drum is not required. Moreover, such once-through boiler is good for both subcritical and supercritical type boilers.

In case of drum boilers, the impurities in feedwater get concentrated due to precipitation process and finally blow down from boiler drum. In this way, the impurities concentration is restricted within allowable limits and the purity of steam admitting into steam turbine can be ensured. On the other hand, once-through boilers do not have drum to carry out precipitation function, therefore, the impurities in feedwater cannot be expelled out and inducted to turbine along with superheated steam. Therefore, in case of once-through boilers, the feedwater purity criterion is more stringent than drum boilers. In order to comply with this requirement of once-through boilers, demineralizing equipment is installed in condensate system.

Salient features of once-through boilers are listed below,

(1) Elimination of steam drum and usage of small diameter tubes for water wall result in reduction of pressure parts weight.

(2) Minimization of heat storage capacity due to less holding water quantity and reduction in thick pressure parts due to elimination of huge drum results in less operating limitations that shorten the duration from start-up to rated load.

(3) Load following capability is high in case of quick load changes.

(4) The risk of feedwater impurities induction to the steam turbine requires stringent and high quality feedwater control system in condensate and feedwater system.

(5) Boiler configuration demands precise and robust control equipment is required.

4.3.4 Selection of Steam Conditions

(1) Steam Condition Selection Strategy for Thermal Power Unit

Thermal power units, based on their operating steam conditions, can be categorized mainly in two types named subcritical power units and supercritical power units. In field of thermal power equipment, technological developments have been made to improve the turbine gross heat rate (kJ/kWh) by raising temperature and pressure of steam admitting to steam turbine. Currently, developments for supercritical to ultra-supercritical thermal units are in progress. Compared to subcritical systems, high efficiency thermal units (supercritical units) can reduce fuel consumption; however, capital investment for such units is also increased due to usage of superior quality alloys to withstand high temperature and pressure of steam.

The definition of Subcritical, Supercritical and Ultra-supercritical is as follows:-

- Subcritical:
  The main steam pressure at the steam turbine inlet is lower than 22.1 MPa(a). Generally, the drum type boiler is adopted.
- Supper–Critical：
  The main steam pressure at the steam turbine inlet is higher than 22.1 MPa(a) and the main steam or the reheat steam temperature is up to 566 degree Celsius. Generally, the once-through type boiler is adopted.
- Ultra–Supper–Critical：
  The main steam pressure at the steam turbine inlet is higher than 22.1 MPa(a) and the main steam or the reheat steam temperature is higher than 566 degree Celsius.

Keeping in view the above stated facts, steam selection is carried out using following criteria,

(1) The proposed system has a reasonable and positive tradeoff between capital investment and savings in fuel cost.

(2) By adopting highly efficient system, CO_2 emissions is reduced as compared to previous coal fired thermal units.

(3) The proposed system is highly reliable.

(2) Selection of steam conditions

The state of the art standard single unit capacity connected to India grid system is 660 MW (gross), therefore, supercritical system is more appropriate.

Regarding steam temperature, supercritical and ultra-supercritical boilers have no choice other than once through boilers and do have proven operation at main steam and reheat steam temperature of 600ºC. Table 4.3-3 shows the experience list of once-through boilers used in Japan.

In this proposed power unit, utilizing the best past experiences, steam conditions of 26.48 MPa(a), 600/600ºC are applied to realize the high efficiency. As this is an application of proven technology in ultra-supercritical units, it is considered as highly reliable technology.

Table 4.3-3 Experience List of Ultra-Supercritical Once-through Boilers in Japan (600ºC Class)

No.	Utility Company	Name of P/S	COD Y/M	Fuel	Output (MW)	Turbine inlet press. (atg)	Temp. (˚C) Main/Reheat	Boiler supplier	Turbine supplier
1	Hokkaido	Tomato-Atsuma 4	2002/06	Coal	700	255	600/600	IHI	MHPS
2	Tohoku	Haramachi 2	1998/07	Coal	1,000	250	600/600	MHPS	MHPS
3	Tokyo	Hitachi Naka 1	2003/12	Coal	1,000	250	600/600	MHPS	MHPS
4	Tokyo	Hirono 5	2004/07	Coal	600	250	600/600	MHPS	MHPS
5	Chugoku	Misumi 1	1998/06	Coal	1,000	250	600/600	MHPS	MHPS
6	J-Power	Tachibanawan 1	2000/07	Coal	1,050	255	600/610	IHI	Toshiba
7	J-Power	Tachibanawan 2	2000/12	Coal	1,050	255	600/610	MHPS	MHPS
8	J-Power	Isogo 1	2002/03	Coal	600	255	600/610	IHI	Fuji Electric
9	J-Power	Isogo 2	2009/07	Coal	600	255	600/620	IHI	MHPS
10	Tokyo	Hirono 6	2013/12	Coal	600	250	600/600	MHPS	MHPS
11	Tokyo	Hitachi Naka 2	2013/12	Coal	1,000	250	600/600	MHPS	MHPS

4.3.5 Introduction of Ultra-Supercritical Pressure High Efficiency Power Generating Technology

(1) Concept of Ultra-supercritical pressure power generating system

By applying Ultra-supercritical Pressure system with higher steam temperature, the plant efficiency is increased as shown in Figure 4.3-1 and also CO_2 emission can be decreased for environment-friendly.

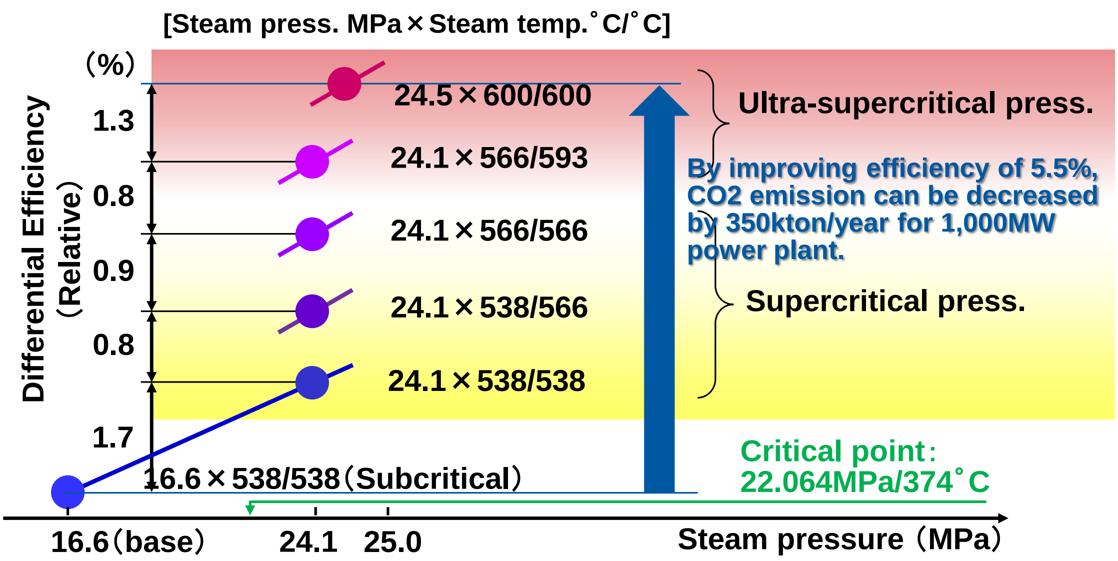

Figure 4.3-1 Improvement of Plant Efficiency with Steam Condition

(2) Boiler Type

As for the boiler type, supercritical pressure once-through boiler which can be operated with sliding pressure mode from supercritical pressure to subcritical pressure region is applied, and the superior operation performance and the high reliable construction has been proven through the abundant operating experience.

Figure 4.3-2 and Table 4.3-4 compare the concept of drum boiler and once-through boiler. In the drum boiler, since the drum outlet temperature is fixed on the saturated temperature at the steam drum pressure, the saturated steam is superheated only in the superheater. By this restriction, the maximum steam temperature is limited to 566/566ºC in the drum boiler.

However, the once-through boiler does not have such fixed temperature restriction at the drum, and the water wall outlet temperature can be above the saturated temperature (slightly superheated). Then the main steam temperature and hot reheat temperature can be designed to be more than 600/600ºC in the once-through boiler.

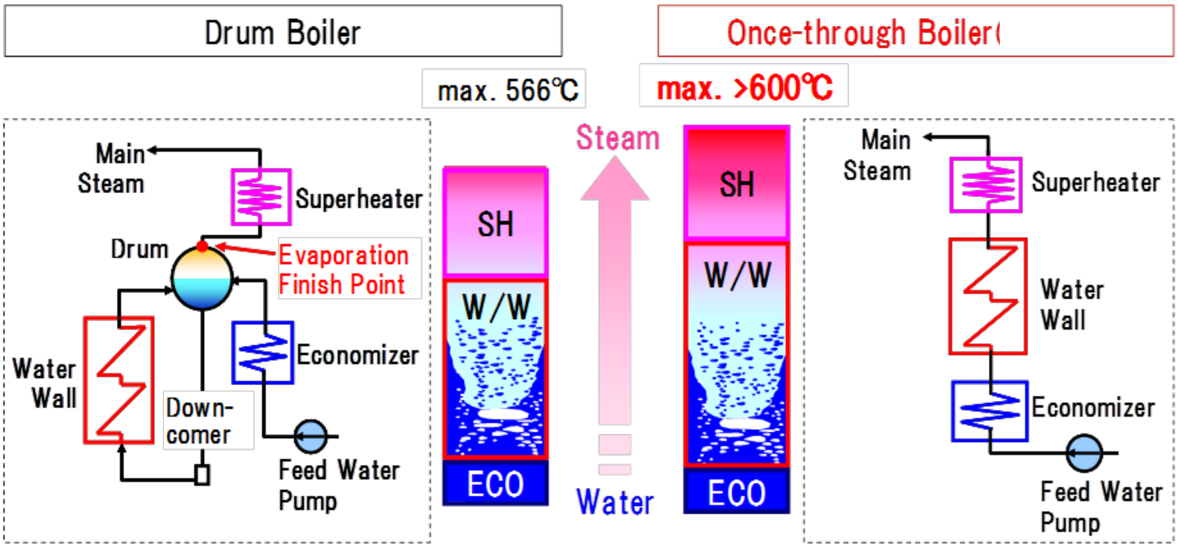

Figure 4.3-2 Concept of Drum Boiler and Once-through Boiler

Table 4.3-4 Concept of Drum Boiler and Once-through Boiler

Suitability	Drum Boiler	Item	Once-through Boiler	Suitability
Bad	Manufacturing limitation on drum size	Large capacity	To consider limitation on system configuration of auxiliary equipment	Good
Bad	Limited to subcritical pressure	High pressure	supercritical～ Ultra-supercritical	Good
Bad	As there is fixed point of steam separation in the steam drum, there is limitation to the heating surface arrangement.	High temperature	Since the water flowing through the tube is continuously converted into steam due to the furnace heat absorption, there is a big margin to the heating surface design.	Good
Good	The impurities in feedwater get concentrated due to precipitation process and finally blow down from the drum and the purity of steam admitting into steam turbine can be ensured.	High feed water quality	As the boiler water quality cannot be conditioned by blowdown of boiler water, higher quality of feed water is required.	Bad

(3) System Components

A system outline of drum boiler and once-through boiler is indicated in Figure 4.3-3.

The major characteristics of once-through boiler compared with drum boiler are the start-up bypass system, the start-up recirculation system and the condensate polisher unit. These systems are not installed in the drum boiler.

During Start-up, the superheater outlet steam will be bypassed the HP turbine through the start-up bypass system until the steam conditions become acceptable to the turbine.

For faster start up, the start-up recirculation system is installed to recirculate water from the separator outlet to the economizer inlet for heat recovery.

The condensate polisher unit is installed to remove mineral matter from condensate water. (see Subsection (5))

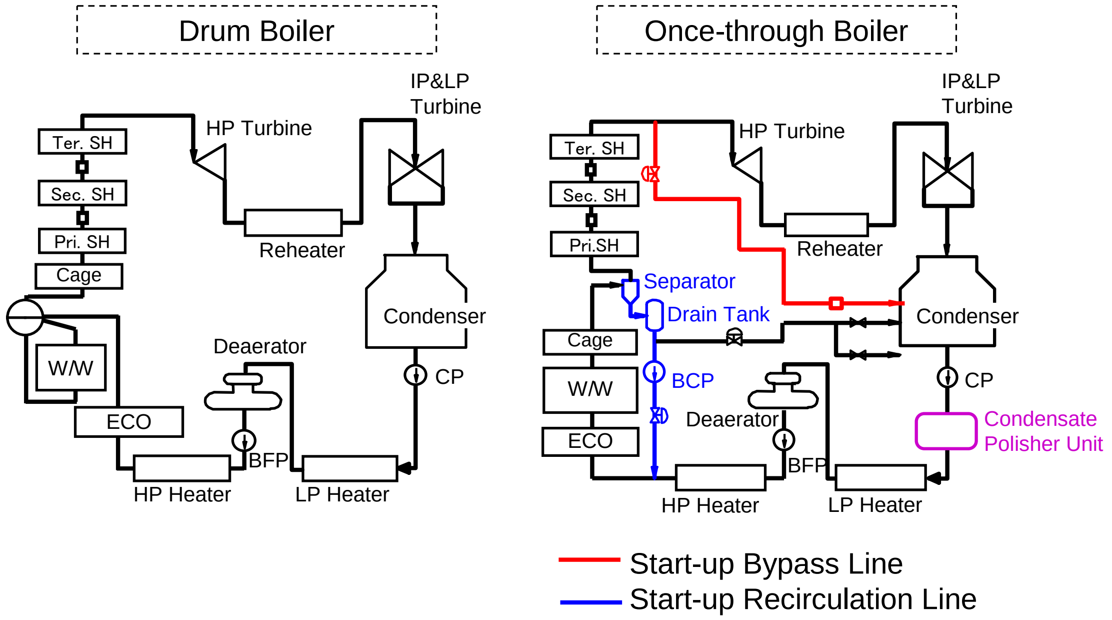

Figure 4.3-3 System Outline of the Drum Boiler and the Once-through Boiler

(4) Operation Characteristics

The water holding capacity of the once-through boiler is much smaller than that of the drum boiler because of lack of the drum. Additionally, the once-through boiler does not have thick wall pressure parts like the drum compared with the drum boiler. Because of that, heat capacity of the once-through boiler is smaller than that of the drum boiler. In other words, the once-through boiler has advantages to the drum boiler in fast start up and higher load ramp rate.

Comparison of operation characteristics between drum boiler and once-through boiler is shown in Table 4.3-5. Water quality control is mentioned in Subsection (5).

Furthermore, by adopting supercritical sliding pressure type, it is possible to increase turbine efficiency over the whole load range including the partial load and to decrease turbine thermal stress.

Table 4.3-5 Operation Characteristics of Drum Boiler and Once-through Boiler

Item	Drum Boiler	Once-through Boiler
Heat Storage of Metal	Much	Less
Response Speed	Base	Faster
Start up Time	Base	Faster
Load Ramp Rate	Base	Higher
Water Quality Control	Drum Blowdown (Make-up water increase)	Strict Water Quality Requirement (Condensate Polisher required)

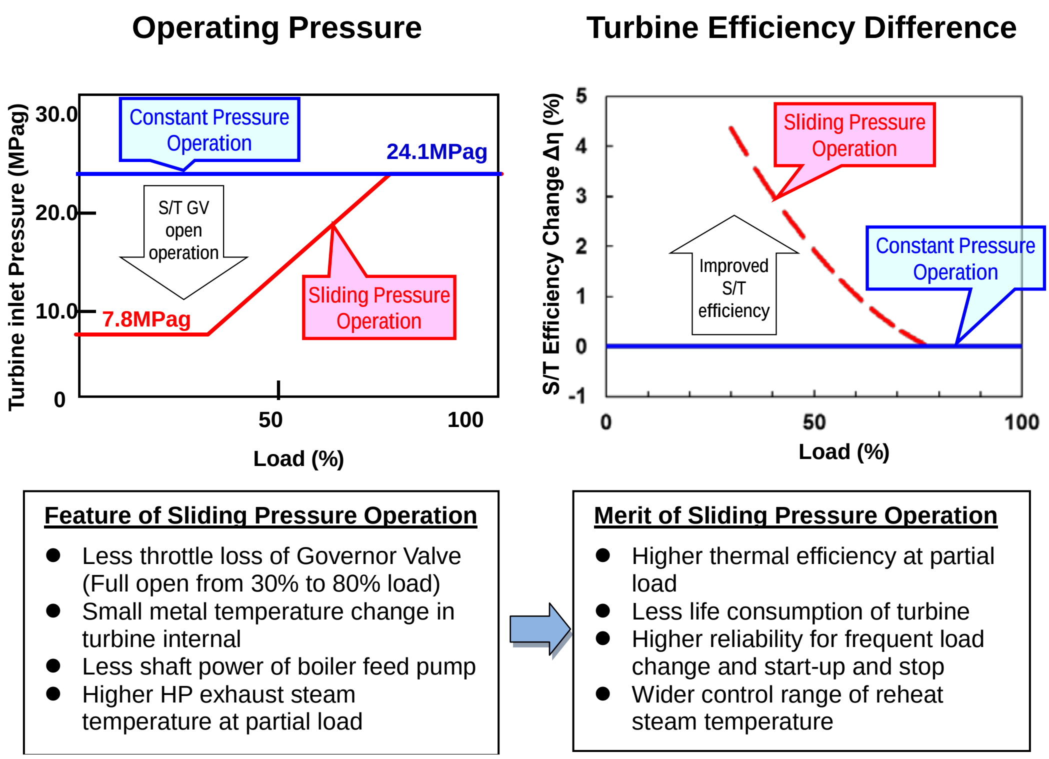

Figure 4.3-4 Comparison of Constant pressure and Sliding Pressure Operation

(5) Water Quality Control

In the drum boiler, contamination in feed water will be separated from steam in the drum and concentrated in drum water. Thus, water quality can be maintained by blowing down from the drum. In the once-through boiler without steam drum, on the other hand, contamination will pass through to the superheater and the turbine because no water-steam separation will occur. It may cause tube leak by overheating due to scale adhesion on the inner wall of tubes. Therefore more stringent water quality control is necessary for the once-through boiler. The following methods are usually applied.

- A condensate polisher is installed to clean up condensate water.
- Volatile chemical materials like hydrazine and ammonia are used for treatment of water.
- Strict criteria of water quality are applied to prevent scale in the boiler tubes.

Table 4.3-6 shows regulation of water quality for boilers in JIS (Japanese Industrial Standards) B 8223:2006 for example.

Table 4.3-6 Criteria of Water Quality for Drum Boiler and Once-through Boiler

	Drum Boiler	**Once-through Boiler (AVT)**
Operating Pressure	15 ~ 20MPa	>20MPa
pH (25ºC)	8.5 ~ 9.7	
Electrical Conductivity (mS/m, 25ºC)	≦0.05	≦0.025
Dissolved O_2(μgO/L)	≦7	
Fe(μgFe/L)	≦20	≦10
Cu(μgCu/L)	≦5	≦2
Hydrazine(μgN_2H_4/L)	≧10	
Silica(μgSiO_2/L)	-	≦20

(6) Materials

Compared with the drum boiler, higher grade materials are needed for the supercritical pressure once-through boiler because of higher steam temperature (600°C or more).

The application range of high temperature materials are shown in Figure 4.3-5 with red.

The applied materials for high temperature parts are specified in Section 5.2.1 of Chapter 5. These materials have also been experienced in 600°C class USC plants in Japan.

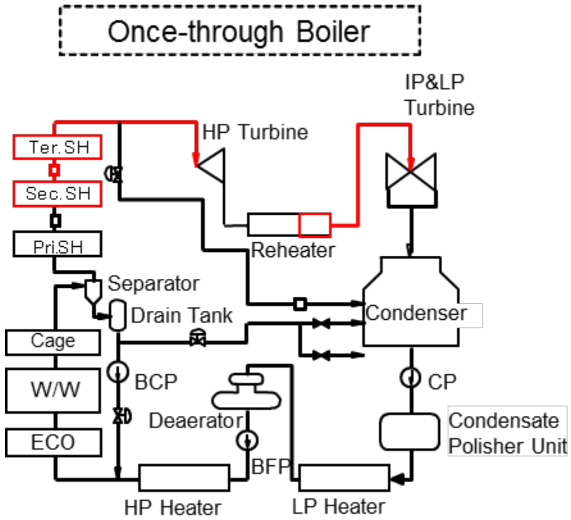

Figure 4.3-5 Scope Figure of High Temperature Materials

4.3.6 Air Quality Control Systems (AQCS)

Considering the CAPEX and OPEX economics, ease of procurement of necessary absorbent and chemicals, marketability of by-product, and so on, the following AQCS equipment is installed to achieve emission limitations mentioned above.

Figure 4.3-6 shows a pattern diagram of entire AQCS.

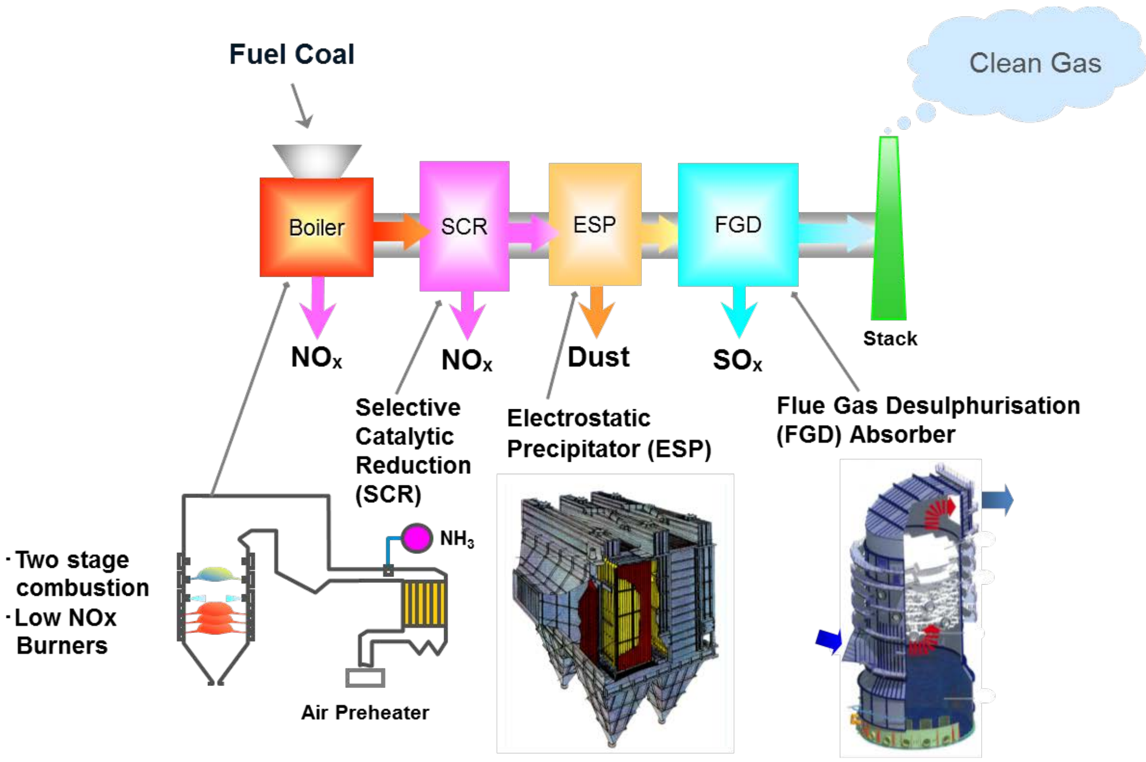

Figure 4.3-6 Overview of Air Quality Control System

(1) NOx (nitrogen oxide) Reduction

The latest low NOx burners, two-staged combustion and flue gas denitrification system with selective catalytic reduction (SCR) are adopted to enable to achieve the planned NOx emission value.

The SCR system is installed between a boiler economiser and air preheater.

(2) SOx (sulphur oxide) Reduction

Almost all sulphur content in the fuel coal is vaporised and passed into the boiler flue gas. Therefore, a flue gas desulphurisation (FGD) system is installed to achieve the planned SOx emission value. The type of FGD system is the wet limestone-gypsum process as described in chapter 5 section 5.2.11. Besides, a flue gas reheating system is also installed to prevent white smoke from the stack and to improve the diffusion of the flue gas.

(3) Dust Reduction

Dust included in the boiler flue gas is removed by an electrostatic precipitator (ESP) and FGD absorber to achieve the planned emission value.

CHAPTER 5

CONCEPTUAL DESIGN OF COAL-FIRED POWER PLANT

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CONCEPTUAL DESIGN OF COAL-FIRED POWER PLANT

5.1 Basic Design

Two coal firing thermal power plants with unit capacity of 660MW which is the standard capacity in India are designed to burn Indian domestic coal. In the recent years in India, since it becomes increasingly concerned about the environment, the eco-friendly and the state-of-the-art technologies are introduced to achieve the new environmental emission regulation.

5.2 Power Plant Design

5.2.1 Boiler and auxiliary Equipment

(1) Basic Specification

The basic specification of the boiler equipment is shown in Table 5.2-1.

Table 5.2-1 Basic Specification of the Boiler

Item	Spec
Type	Supercritical Sliding Pressure Once-through Boiler （Radiant Reheat Outdoor Type）
Main steam flow	1,970.432 t/h(BMCR)
Fuel	Pulverized Coal, Distilled Oil (start up)
Steam Condition Superheater outlet pressure Superheater outlet temperature Reheater outlet pressure Reheater outlet temperature	 27.2 MPa(a) 603ºC 5.04 MPa(a) 603ºC
Steam Temperature Control Method Main Steam (MST) Reheat Steam (RST)	 Fuel/Water Ratio + Two-stages Spray Attemperator Gas Biasing, Spray Attemperator (Emergency)
Steam Temperature Control Range	MST: 50%L ~ 100%L RST: 50%L ~ 100%L
Load Ramp Rate	50% ~ 100%TMCR 3%/min 35% ~ 50%TMCR 1%/min
Minimum load	30%BMCR
Operation Method	Sliding Pressure
House Load Operation	Enable
Furnace Type	Vertical Water Wall (Rifle Tube)
Burner Arrangement	Circular Firing
Burner Type	Low NO_x Burner

Item	Spec
NOx Control Method	Low NOx Burner, Two-stage Combustion
Coal Pulverizer	Vertical Roller Mill 8 sets (1 stand-by)
Draft System	Balanced Draft
Air Heater	Tri-sector type, 50% × 2
Forced Draft Fan	Axial type, 50% × 2
Primary Air Fan	Axial type, 50% × 2
Induced Draft Fan	Axial type, 50% × 2

The boiler is designed for outdoor operation, and suspended from the structural steelwork within the boiler building. The coal bunkers are located along the both side of the boiler unit with the coal pulverizers installed below them. Total eight (8) sets of coal bunkers and vertical mills are provided for the boiler unit, of which each four (4) sets are located at each side of boiler unit. The coal feeders which are arranged below the bunkers feed the coal into the pulverizer inlet chutes. The back end of the boiler is equipped with two selective catalyst reduction (SCR) system, two regenerative air heaters (AH), two electrostatic precipitators (ESP) followed by two induced draft fan (ID-fan), two regenerative gas-gas heaters (GGH) and two flue gas desulphurization (FGD) plant.

The boiler is designed with adequate tube spacing to avoid plugging and ash build-up, soot blowers for proper cleaning and arrangement considering maintenance access. A boiler side view image is shown in Figure 5.2-1.

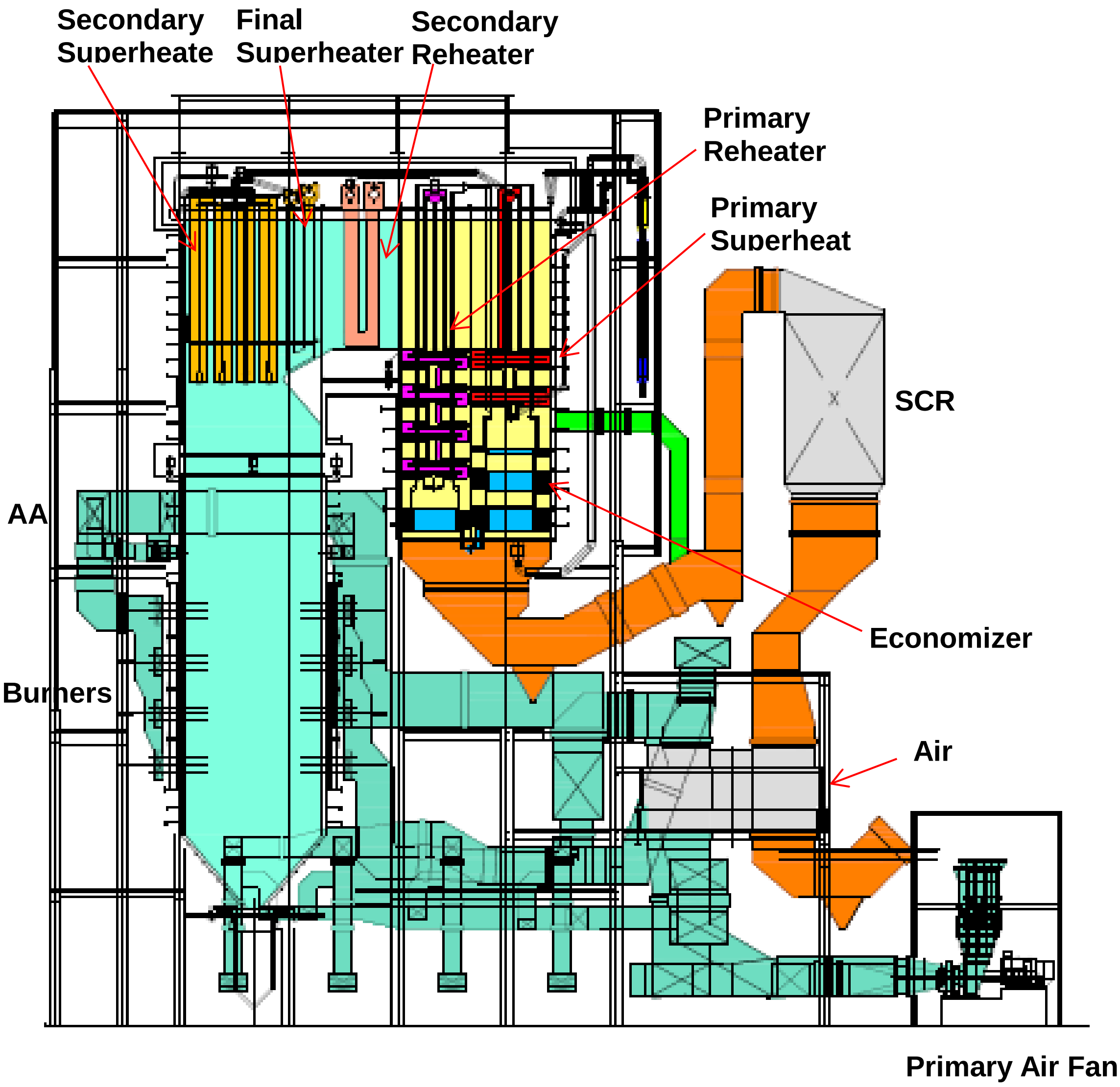


Figure 5.2-1　Boiler Side View Image

1)　General Description

The boiler is a supercritical sliding pressure once-through boiler of the two-pass type constructed with the vertical type water wall, three-stage superheater and two-stage reheater.

The feed water is evaporated in the water wall, and then heated in the superheater and supplied as the main steam to the HP turbine. The HP turbine exhaust steam flows through the reheat section and is passed to the IP turbine.

2)　Boiler Design Code and Standard

The boiler is designed in accordance with ASME Boiler & Pressure Vessel Code.

3) Features of Boiler

- Boiler Type: Two-pass type supercritical sliding pressure once-through boiler
- Circular firing system with two fire vortex equipped with sixty-four (64) sets low NOx burners are provided. A burner level, which are connected to a mill, consists of eight burners located at eight corners of the front and rear walls (four corners at each wall), and total eight burner levels are arranged.
- The furnace structure image is shown in Figure 5.2-2.
  The furnace design consists of a vertical water wall with rifle tube having superior heat transfer characteristic, which is simple structure. The orifices are installed individually at inlet of water wall tubes in order to optimize fluid flow for maintaining uniform metal temperature distribution according to heat absorption fluctuation caused by unstable combustion and slag accumulation on the water wall, etc.

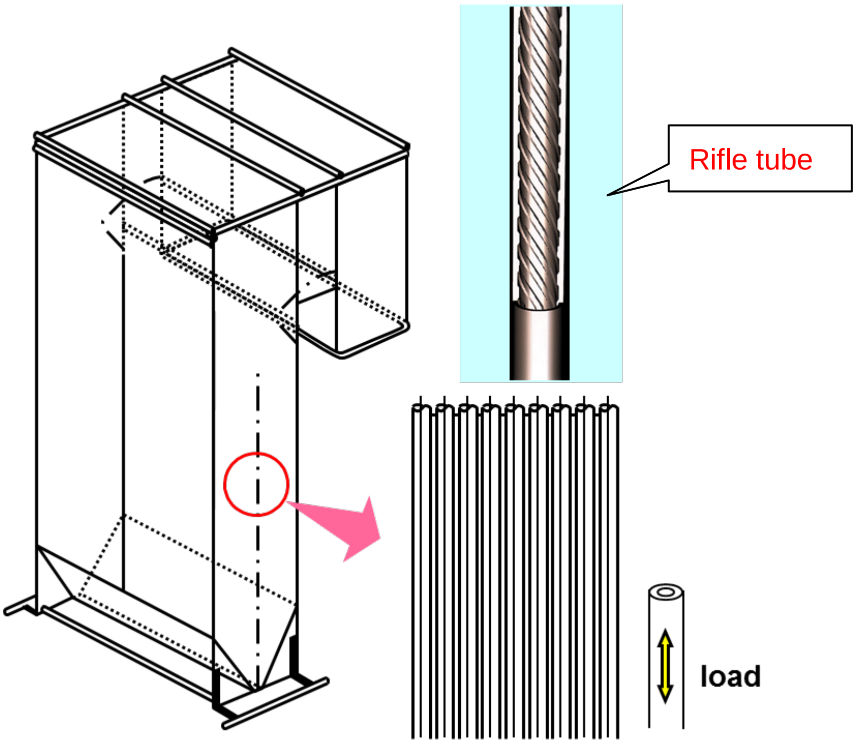


Figure 5.2-2 Furnace Structure Image

4) Selection of Pressure Parts Material

As shown in Table 4.2-3, the highest level steam condition as USC power plant, of which high reliability have been demonstrated through the many operating experience of commercial units in Japan, is applied

Candidate materials for pressure parts are shown in Table 5.2-2. These materials have also been demonstrated through USC plants with reliable operation experience.

Table 5.2-2 Candidate Materials for the Boiler Pressure Parts

Parts		Operating Temperature	Materials
Tubing	Furnace Water Wall	350 ~ 520ºC	(A210) 1Cr0.5Mo(A213T12)
	Superheater	450 ~ 600ºC	1Cr0.5Mo(A213T12) 2.25Cr1Mo (A213T22) 9Cr1MoV(A213T91) 9Cr1.8W (A213T92) 18Cr10NiCb(A213TP347HFG) 18Cr10NiTiCb(JIS: SUS321J1TB) 18Cr9Ni3Cu(A213/UNS,S30432)
	Reheater	350 ~ 610ºC	0.5Mo(A209T1a) 1Cr0.5Mo(A213T12) 2.25Cr1Mo(A213T22) 9Cr1MoV(A213T91) 9Cr2W(A213T92) 18Cr10NiCb(A213TP347HFG) 18Cr10NiTiCb(JIS: SUS321J1TB) 18Cr9Ni3Cu(A213/UNS,S30432)
Piping and Header	SH Outlet Header Main Steam Pipe	600ºC	9Cr1MoV(A335P91) 9Cr2W(A335P92)
	RH Outlet Header、 Hot Reheat Pipe	600ºC	9Cr1MoV(A387Gr91) 9Cr2W(A335P92)

5) Water and Steam System

Figure 5.2-3 shows an outline of the main water and steam system.

A type of boiler is a once-through boiler with two-pass construction which is designed as a fully welded boiler with flue gas-tight membrane casing. The steam pressure is supercritical as mentioned in Section 5.1 of Chapter 5. The heat is transferred mainly by radiation to the enclosing water walls.

The boiler has platen heating surface bundles on the top of the furnace and horizontal heating surface bundles in the back pass which are heated by the flue gas mainly by convection. The heating surface sections consist of superheaters (SH), reheaters (RH) and economiser (ECO).

Condensate water from the condenser is first boosted by the condensate pump and flows into the condensate polisher and the gland condenser. The condensate is boosted again by the condensate booster pump and flows to the LP-heater and the deaerator. Afterwards, the deaerated water is fed to the boiler as feed water via HP-heaters pumped by the feed water booster pump and the feed water pump.

The feed water first flows through the ECO, counter to the flue gas, and is then fed downwards through connecting pipes, where it enters the vertical membrane walls of the furnace. The fluid coming out of the vertical water wall is fed to the steam-water separator located in rear of the boiler via the roof and back pass wall.

Here the water contained during starting up and in partial load operation below minimum once-through load is separated from the steam. The separated steam flows into the superheaters via the roof and the convection pass wall.

The superheater consists of the three-stage. The steam is heated first in the horizontal type primary superheater through which the steam flows upward and counter to the gas flow. The steam then passes through the pendant panel type secondary superheater located at upper furnace in a parallel flow to the flue gas. Afterwards, the steam flows through the pendant final superheater in which the steam flows parallel to the flue gas. Finally the superheated steam is supplied to the HP turbine via the main steam pipe (MSP).

The spray attemperators for temperature control are installed between the primary SH and the secondary SH and between the secondary SH and the final SH.

The steam is used in the HP turbine and returns to the boiler through cold reheat line. The cold reheat steam is heated again in the two-stage reheater which consists of the horizontal type primary reheater and the pendant type final reheater, and then flows to the IP turbine and the LP turbine.

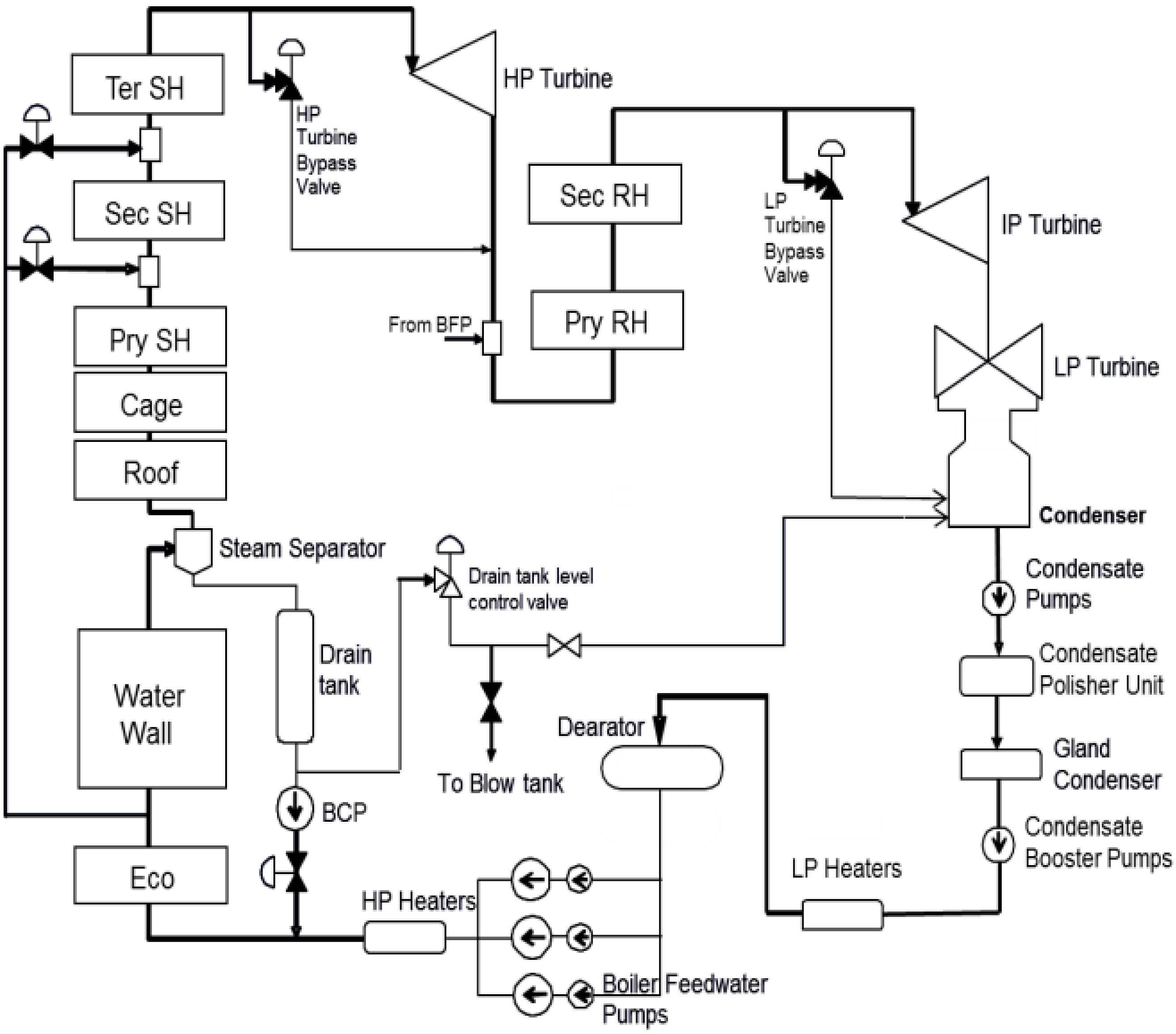


Figure 5.2-3 Water and Steam System

6) Steam-water Separator

Image of the steam-water separator is shown in Figure 5.2-4. The separator is installed in rear of the boiler and the steam leaving the water wall and back pass wall flows into it. The steam separator has tangentially arranged inlet nozzles in the upper section, a steam outlet nozzle on the top and a water outlet nozzle with a vortex baffle plate on the bottom.

The water separated in the water separator is stored in the water separator drain tank, and recirculated to the economizer inlet by BCP.

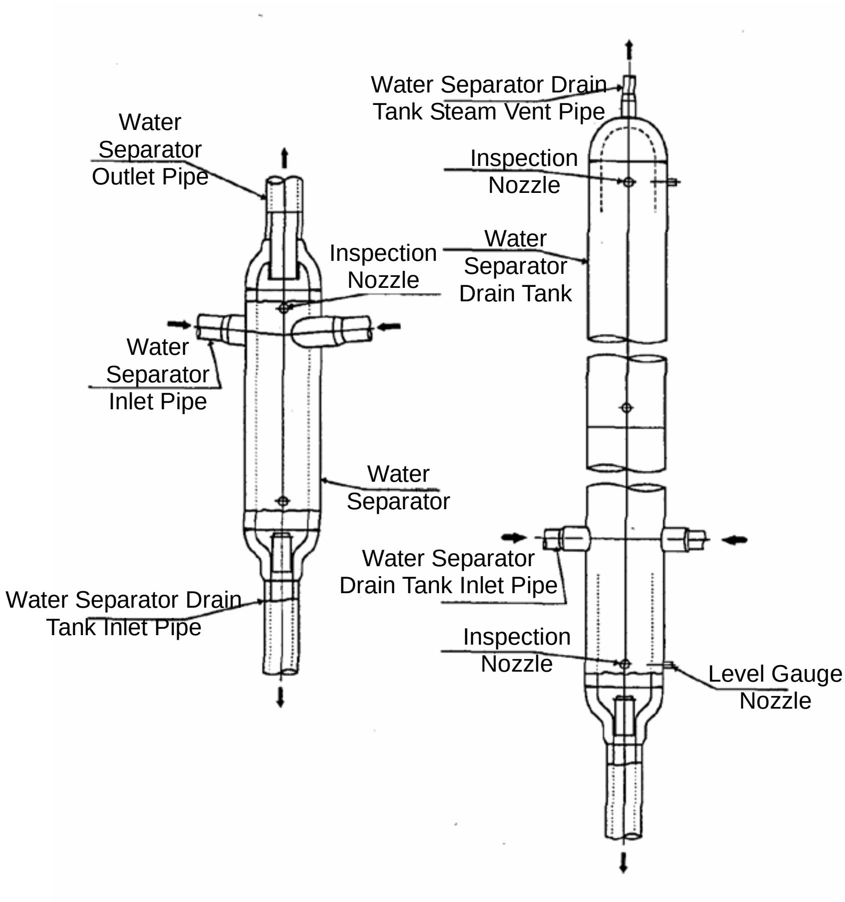


Figure 5.2-4 Steam Separator and Drain Tank

7) Boiler Recirculation System and Boiler Start-up System

The minimum flow through the ECO and evaporator, during starting up and low load operation below minimum load for once-through operation, is achieved by forced circulation provided by a boiler circulating pump (BCP). Below minimum once-through load water circulates from separator outlet to ECO inlet header.

8) Turbine Bypass System

During start-up and in the event of any failure of the steam turbine or some pressure increase in the boiler, the main steam as well as the hot reheat steam can be bypassed by the HP turbine bypass and the LP turbine bypass. The main steam pipe and the cold reheat pipe are connected by the HP turbine bypass pipe on which a HP bypass valve is installed. In case operating condition goes wrong that the boiler cannot follow the turbine and the turbine cannot accept steam flow, the HP turbine bypass performs as a buffer and pressure relief.

The HP turbine bypass also fulfils the function of high pressure safety valves when load rejection happens. In this case, the HP turbine bypass is opened pressure dependent, reliably and simultaneously like a safety valve.

The LP turbine bypass connects the hot RH lines upstream of the IP turbine to the condenser in which the steam is directly exhausted to the condenser in case of turbine bypass operation. Therefore the steam has to be pressure relieved and cooled down by injection of condensate water spray before entering the condenser.

Benefits of HP and LP turbine bypass are as follows:-

(1) Improvement of start-up characteristic

(2) Improvement of operability during load change by absorbing load gap between the boiler and the turbine

(3) House load operation or boiler single operation

(4) Back up of the HP safety valve

9) House Load Operation

The HP and LP turbine bypass described above enable the house load operation in case of load rejection. During the house load operation, to keep auxiliary power only the IP and LP turbine are operated. The boiler is operated at minimum load and excess steam flow for generating auxiliary power is bypassed to the condenser by the LP-turbine bypass. House Load Operation should not maintain more than 2 hours to avoid erosion of the LP-turbine last-stage blade.

10) Air and Gas System

Figure 5.2-5 shows the outline of the air and gas system. The system is designed as double flow, and axial type fans are applied to FDF, IDF and PAF as the main fans to save auxiliary power consumption.

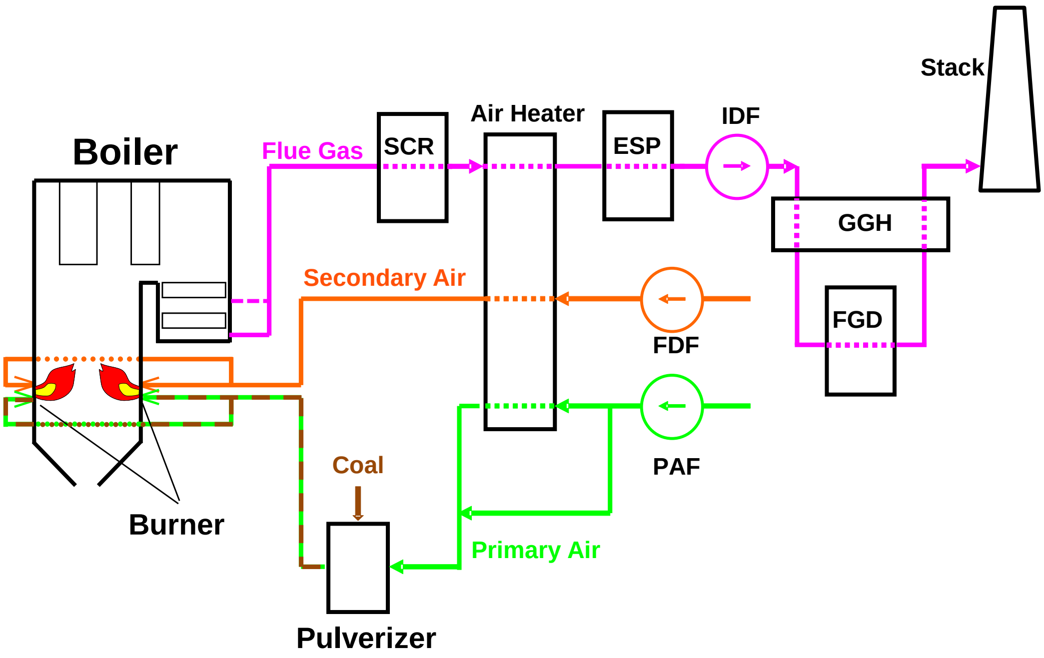


Figure 5.2-5 Air and Gas System

(2) Burners and Mills

The coal firing system is equipped with eight (8) coal bunkers, eight (8) coal feeders, eight (8) mills and sixty-four (64) burners. The maximum boiler output shall be obtained in seven (7) mills operation mode (1 for stand-by) when firing the design coal. The minimum stable boiler load with the design coals is designed 30%BMCR load.

To achieve a low NOx emission, low NOx –burner systems and two-stage combustion system with single-stage Additional Air (AA) ports are applied. Sixty-four (64) burners are located on 8 elevations and 8 corners on the both front and rear wall of the furnace as circular firing system with two fire-vortex. Thirty-two (32) light fuel oil burners having capacity of 30%BMCR, which are located on 4 elevations between each coal burner and 8 corners, are used for warm-up during start-up and stop, back-up and igniting for coal burner. Light oil burners are ignited by HEA (High Energy Ark) ignitors.

1) Burner

Figure 5.2-6 shows outlines of the low-NOx burner. Controlled mixing of the fuel and the combustion air forms a highly reductive condition surrounding the burner and NOx reduction in a high temperature reducing flame. Additionally, because the flame stabilizer accelerate rapid ignition, the combustion performance is improved at the same time as low NOx emission.

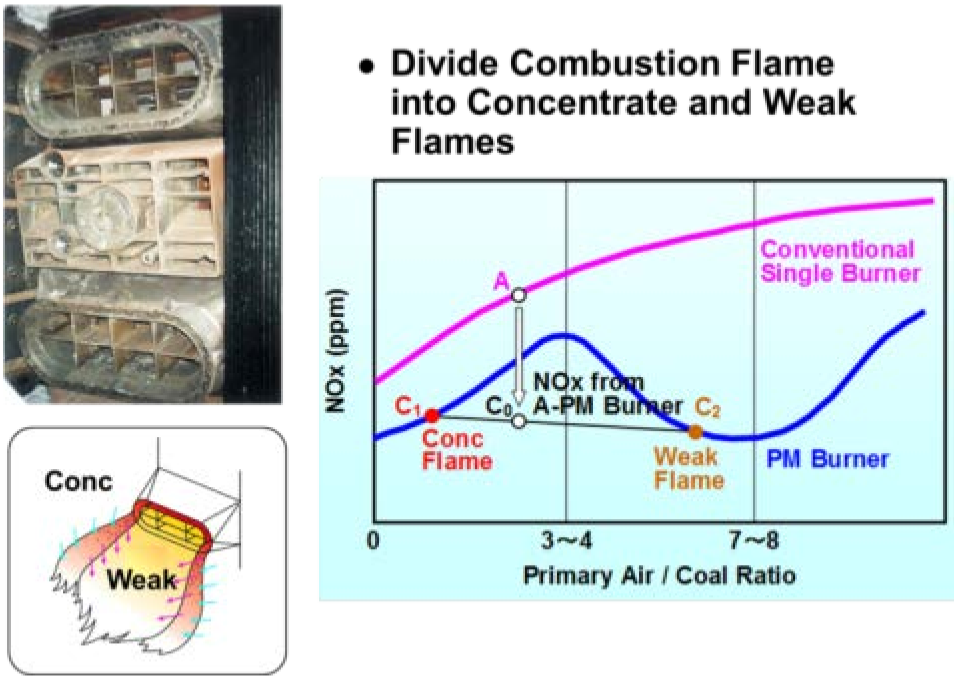


Figure 5.2-6　Low NOx Burner

2)　Coal Bunkers

Coal handling system to mills is composed of eight (8) coal bunkers and coal feeder. Coal bunkers are conical sections.

3)　Coal Feeders

Raw coal from bunkers are conveyed to mills by coal feeders. Feed rate is measured by gravimetric belt type coal feeders and it is one of the parameters for boiler control.

4)　Vertical Roller Mills

Figure 5.2-7 shows the basic structure of the vertical roller mill.

Eight (8) vertical roller type mills are installed. Requirements for coal pulverizing system are as follows.

- To grind the required coal quantities considering the lowest grindability of coal
- To dry the coal by hot primary air
- To classify the pulverized coal fineness required by combustion performance
- To distribute the pulverized coal equally to burners

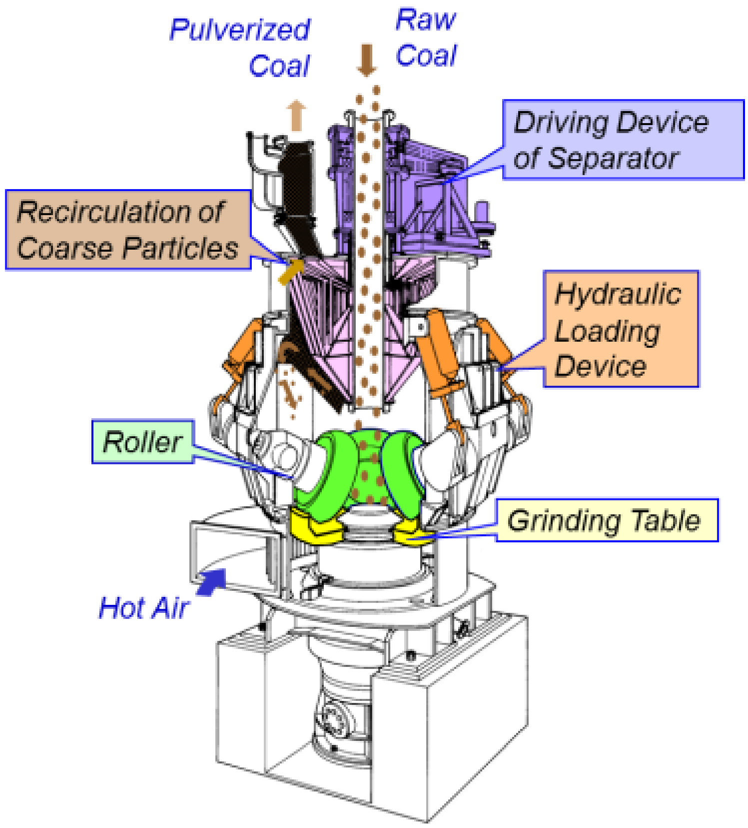


Figure 5.2-7　Basic Structure of the Vertical Roller Mill

The raw coal conveyed from bunkers fall to the grinding table through the center top of mills. The raw coal move to outside of the table by centrifugal force and then they are grinded at the gap between the roller and the grinding table.

The coarse pulverized coal are returned to the grinding table through nozzle rings at the outside of the table by supplying air for carrying and drying. After that, pulverized coal are classified by rotating classifier and fed to burners through coal pipes.

5)　Hydraulic Loading System

The roller mill has a high grindability by not only self-weight of roller but also loading by hydraulic pressure to the table. The mill operating condition, especially in the lower boiler load, is improved by the hydraulic loading system.

(3)　Boiler Auxiliaries

1)　Regenerative Air Pre-Heater (APH)

APH improve combustion efficiency and boiler efficiency by heating combustion air and lowering flue gas losses through heat exchange between combustion air and flue gas.

Two (2) sets of vertical tri-sector type APH are provided.

2) **Forced Draft Fan (FDF)**

Two(2) × 50% FDFs are installed to supply required combustion air.

FDF is constant rotating speed type, driven by the motor and high efficiency axial flow type which has rotor blade variable pitch control. FDF is designed with considering necessary air flow at BMCR and fuel over shoot during load change.

3) **Induced Draft Fan (IDF)**

Two(2) × 50% IDFs are installed to exhaust the flue gas from FGD to stack.

IDF is constant rotating speed type, driven by the motor and high efficiency axial flow type which has rotor blade variable pitch control. IDF is designed with considering necessary flue gas flow at BMCR and fuel over shoot during load change.

4) **Primary Air Fan (PAF)**

Two(2) × 50% PAFs are installed to supply required primary air to the mill at BMCR.

PAF is constant rotating speed type, driven by the motor and high efficiency axial flow type which has rotor blade variable pitch control. PAF is designed with considering necessary air flow at BMCR and fuel over shoot during load change.

(4) Auxiliary Steam System

Auxiliary steam system is composed of steam supply systems from outlet of primary superheater and cold reheat pipe.

Auxiliary steam is supplied through auxiliary steam headers to equipments for steam turbine grand sealing and to heat deaerator during start-up and for boiler soot blower, ash handling system and demineralizer and so on during normal operating condition.

(5) Oil Firing system

Light oil is used as boiler start-up fuel.
Oil firing system is composed of light oil storage tanks and equipments for oil pumps and laying pipes valve meters.

(6) Chemical Dosing System, Sampling System

Combined Water Treatment (CWT), which conducts pH control and oxygen injection simultaneously, is applied and ammonia are used for pH control. During initial plant operation and after major periodic inspection, hydrazine are used for all volatile treatment (AVT) operation to reduce dissolved oxygen.

(7) Compression Air Equipment

The compression air equipments are planned for control and using in-house.

(8) Nitrogen and Steam Sealing Equipment

The nitrogen and steam sealing equipments are planned for safekeeping equipments.

5.2.2 Steam Turbine Generator and Auxiliary Equipment

In this project, a reheat and regeneration cycle will be adopted. Features of the steam turbine and turbine auxiliary units are described below.

(1) Steam turbine

The Steam Turbine will be a tandem-compound unit which consists of three (3) pressure sections i.e. HP section, double flow IP section and four (4) flow LP exhaust configured in two (2) LP sections. Table 5.2-3 shows the specifications, while Figure 5.2-8 shows the general appearance of the steam turbine.

Table 5.2-3 Steam Turbine Basic Specifications

Item	Specifications
Type	Tandem compound Double Flow IP Four (4) Flow LP
Output	660 MW(Gross)
Number of the casing s	HP: 1, IP: 1, LP: 2

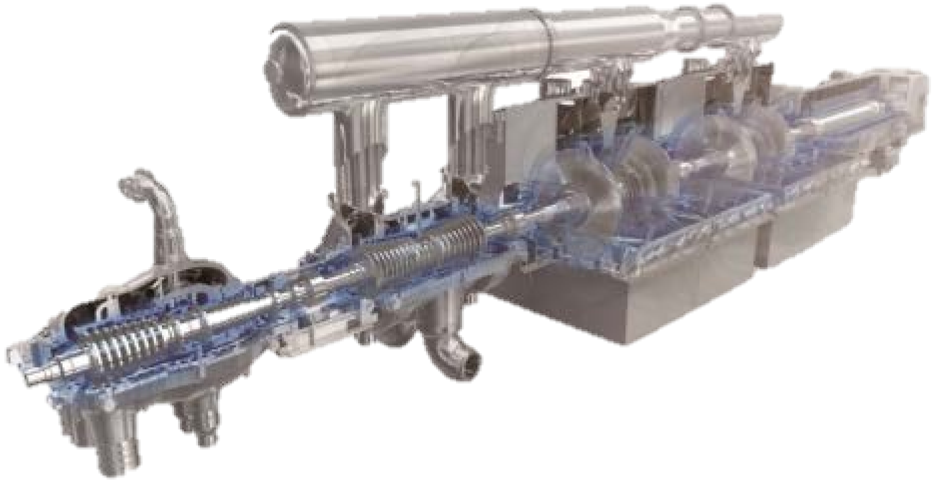


Figure 5.2-8 General Appearance of Steam Turbine

Casing will be the horizontal partitioned type that is easy to inspect and is widely adopted; and the high & intermediate pressure section consists of double shell construction, which is made of cast alloy steel.. The turbine has one (1) HP rotor, one (1) IP rotor and two (2) LP rotors, which are uniformly and solidly fastened with coupling bolts. Rotors are supported by eight (8) journal bearings and are positioned in axial direction by the thrust bearing installed on the middle bearing pedestal between the HP and IP section.

(2) Steam turbine auxiliary equipment

1) Main valves

(a) Main stop valve (MSV)

This hydraulically driven valve will be for shutting off the flow of main steam to the turbine. It will be opened by hydraulic pressure supplied from the electro-hydraulic controller (EHC), and fully closed by hydraulic pressure loss.

(b) Steam control valve (CV)

This hydraulically driven valve, situated behind the MSV, will be for controlling the flow of main steam to the turbines. Opening and closing will be controlled by EHC.

(c) Overload valve (OLV)

This hydraulically driven valve will be fully closed during normal operation, however, at times of overload operation of 102% TMCR or higher, it will direct steam to the high-pressure turbine middle stage bypassing MSV and CV. Through installing an overload valve, it is possible to reduce the pressure loss during normal operation.

(d) Combination reheat valve (CRV)

This hydraulically driven valve combines the reheat steam stop valve, which shuts off the entry of reheat steam to the turbine, and the intercept valve, which controls the flow of reheat steam during emergencies, etc.

2) Gland steam system

Gland steam is for steam-sealing the LP turbine gland in order to maintain vacuum in the condensers.

Before starting and also during low-load operation, the gland steam will be supplied from auxiliary steam, while at times of high-load operation, the steam will be supplied through utilizing leaking steam from the high-pressure turbine gland. Any excess steam that is supplied will be discharged to the low-pressure No.1 feedwater heater or condenser, while the fluid mixture of air and steam discharged after gland sealing will be directed to the gland steam condenser for recovery.

3) Lubricant system

The lubricant system, comprising main oil tank, oil pump, oil cooler and strainer, will feed lubricant to the bearings.

In addition to AC motor-driven oil pumps for use during normal operation, a DC motor-driven oil pump will be installed for use when station power supply is lost. This will make it possible to continuously supply lubricant in order to protect the metal of the steam turbine bearings.

4) Control oil system

In this unit, sophisticated automation of operation will be realized through utilizing EHC to open and close valves. The control oil system, comprising the fluid part of the EHC, will be totally independent from the lubricant system and will possess a control oil tank, control oil pump, filter, oil cooler and accumulator.

5) Steam bypass system

The high-pressure and low-pressure turbine bypass systems will each have capacity of 65% of BMCR and will serve to protect turbines and enable house load operation and boiler single operation at times of load loss.

6) Protective functions

The following protective circuits and activation of the turbine emergency stop valves will be envisaged for turbine protection as shown in Table 5.2-4:

Table 5.2-4 List of Turbine Protective Circuits

No.	Descliption	Protective circuits
1	Electrical over speed	2 out of 3
2	Shaft vibration high	2 out of 2
3	Thrust position abnormal	2 out of 3
4	Lubricating oil pressure low	2 out of 3
5	Main Oil Pump discharge oil pressure low	2 out of 3
6	EHC control oil pressure low	2 out of 3
7	HP exhaust metal temperature high	2 out of 3
8	LP exhaust steam temperature high	2 out of 3
9	Condenser pressure high	2 out of 3
10	Activation from electrical generator protection	1 out of 2
11	D-EHC major failure	-
12	DCS Trip (as required)	-

7) Condensate water system

(a) Condensers

Surface condensing type heat exchanger of dual pressure (HP & LP) type is proposed for each unit of 660 MW Through adopting different inner pressure in each condenser, the condensers will be designed to reduce the mean back pressure of the steam turbines and improve turbine efficiency compared to single pressure condensers. In specific terms, through adopting a system whereby the main cooling water is passed through the condensers in series, the inner pressure in the condenser on the upstream side becomes relatively lower, and that on the downstream side becomes higher.

(b) Condenser Vacuum System

The dissolved gas in steam that flows into the condenser, and the air that flows in from joints, etc. will be discharged by two 100% capacity liquid ring vacuum pumps. The sealing water will be supplied from the condensate system. The two pumps will be operated when vacuum is raised at the start of operation, and only one will operate while the other one is stopped and kept on standby during normal operation. The vacuum pumps will be controlled and monitored by the plant DCS.

(c) Online Tube Cleaning System (COLTCS)

The condenser online tube cleaning system (COLTCS) will facilitate continuous cleaning of the inner side of condenser tubes while the unit is in operation. In this system, in order to wash the thin tubes, sponge balls will be inserted into the cooling water tubes from the condense inlet on the low pressure side. After the sponge balls wash the thin tubes as they pass through the condensers with the cooling water, they will be recovered by a ball collecting strainer at the outlet on the high-pressure condenser. The collected balls will be extracted by a ball recirculation pump and injected back into the condenser inlet pipe.

(d) Condensate Makeup Water System

A makeup water pump will be used to pump water from the pure water tank and replenish the pure water in the condensers. The makeup water piping will be equipped with a condenser level control valve (LCV) for controlling the quantity of makeup water. A line for bypassing the LCV, fitted with a motorized valve, will be used for the initial filling of hotwell with DM water.

(e) Condensate Blow and Spillover System

The condensate water is dumped by the CEP discharge blow-down valve branched from condensate piping upstream of the CPU during the clean-up phase. When condenser water level rises during normal operation, the spillover valve will be opened and condensate will be collected in the condensate tank.

(f) Condensate Extraction Pump

Three vertical axis multi-stage condensate pumps (one spare) having 50% capacity will be installed. The condensate extraction pumps will be controlled by the DCS.

(g) Condensate Polishing Unit (CPU)

Since the once-through boilers here are unable to blow the boiler water in the manner of drum boilers, it will be necessary to implement water treatment inside the system in order to maintain the water quality. The condensate polishing unit will comprise three demineralizing vessels and one regeneration system. Through passing condensate through ion exchange resin inside the demineralizing vessels, demineralization will be conducted as the CATION impurities is exchanged with CATION resin of Hydrogen (H+) and ANION impurities are exchanged with ANION resin of Hydroxyl (OH-). Since it will be necessary to regularly regenerate the ion exchange resin, it will be transferred to the regenerative system to undergo regeneration based on hydrochloric acid and sodium hydroxide. During the regeneration, it will be possible to conduct full load operation using only two demineralizing towers. The wastewater that accompanies the regeneration will be neutralized in the neutralizing tank and then sent to the wastewater treatment system.

(h) Chemical Treatment

Concerning the plant water treatment method, combined water treatment (CWT), which is a type of oxygen treatment, will be conducted during normal operation, while all volatile treatment (AVT) will be adopted during unit startup. In each method, ammonia will be used for regulating pH. Moreover, during CWT operation, oxygen will be injected in order to keep the dissolved oxygen concentration at an appropriate level, while during AVT operation, hydrazine will be injected as an oxygen absorber in order to keep dissolved oxygen down.

(i) Gland Steam Condenser

This will be a multi-tubular heat exchanger for drawing gland steam into the shell and condensing it by means of heat exchange with the condensate running through the tubes. This will be installed with the goals of sucking gland steam and recovering water and heat to the system.

(j) Low-pressure feedwater heater

The feedwater heaters will be installed in order to preheat the feedwater with extracted steam from the steam turbine, thereby increasing the plant efficiency. The condensate system will have four feedwater heaters (No.1 to No.4): No.1 and No.2 will be installed as integrated units with the neck of the condenser , while No.3 and No. 4 will be installed as independent feedwater heaters in the turbine room. Each feedwater heater will be a horizontal multi-tubular type that heats condensate inside tubes by using steam that has been drawn inside the shell. The heating steam in the No.1, No.2 and No.3 feedwater heaters will be bled from the

LP turbines, while the heating steam for the No.4 feedwater heater will be bled from the IP turbine. In order to improve the cycle efficiency, drainage water from the No.3 and No.4 feedwater heaters will be recovered in the LP heater drain tank, pressurized by pump, and then returned to the condensate system between the No.3 and No.4 feedwater heaters.

(k) Deaerator

A horizontal, single-barrel type spray tray deaerator will be adopted. In addition to removing dissolved gas (a cause of pipe corrosion) from condensate, the deaerator will also serve as a storage tank for feedwater, and it will have sufficient capacity to enable operation of the BMCR for three minutes from the normal water level to the low water level. Deaeration will be conducted by means of reducing the solubility of dissolved gas in condensate via heating: first, condensate will be sprayed into direct contact with steam from the spray device on top of the unit; moreover, it will be brought into contact with steam by flowing condensate into a tray installed at the bottom of the spray device, thereby ensuring that deaeration is certainly carried out. During normal operation, bleeding will be conducted from the IP turbine, while heating will be conducted by low-temperature reheat steam during startup. The deaerator will be installed at sufficient height in order to secure suction head of the latter feedwater pump booster pump.

(l) Low-pressure cleanup system

The LP Clean-up system is used at the time of plant start-up. The LP clean-up lines will branch off from the down comer pipes stretching from the deaerator to the steam and motor-driven feedwater pumps. Depending on water quality, the condensate that passes through here will either be recovered in the condenser or discharged to the flush tank.

8) Feedwater system

(a) Steam feedwater pumps (TDBFP)

Two (2) × 50% Turbine Driven BFPs with Variable speed Steam Turbine for each TDBFP is provided. Main BFP is connected to the drive turbine with suitable coupling and the booster pump with a gear box. Each TDBFP is a multi-stage, horizontal, barrel type, variable speed centrifugal type pump and booster Pump is of horizontal, single stage centrifugal, constant speed type. Drive turbine of TDBFP will get normal motive steam from extraction from IP turbine in the load range of 30% to full load. During low load conditions or bypass operation, when the extraction steam pressure is inadequate, steam from CRH extraction will be used. Exhaust from each drive turbine is led individually to the HP and LP Surface Condenser respectively. For thrust balancing, the majority of thrust is nullified by the back-to-back impeller stage arrangement and the remaining thrust forces are balanced by balance drum. BFP lube oil system is common with the drive turbine lube oil system for supply of lube oil to the pump bearings and the gear box. Each lube oil system consist of AC driven main lube oil pumps, DC driven emergency oil pump, etc. The cooling water from the Closed Cycle Cooling Water (CCCW) system is supplied to BFPT lube oil coolers and mechanical seal water coolers of main BFP and Booster pump.

(b) Motor-driven feedwater pump (MDBFP)

One (1) × 30% capacity MDBFP is multi-stage, horizontal, barrel type, motor driven, variable speed centrifugal type pump for the plant start-up & standby purpose in case of one TDBFP failure. Both booster pump and main BFP pump are driven with a common motor. BFP Booster Pump is of horizontal, single stage centrifugal, constant speed type pump is located on the other end of the motor by the same motor shaft at constant speed. The main BFP being of higher operating speed than the motor, a variable speed hydraulic coupling is used in between the motor and the main BFP and other end it directly coupled to BFP booster pump. For thrust balancing, the majority of thrust is nullified by the back-to-back impeller stage arrangement and the remaining thrust forces are balanced by balance drum. MDBFP set has its own dedicated lube oil system for supply of lube oil to the main BFP, booster pump, hydraulic coupling and motor. The lube oil is supplied from the hydraulic coupling which serves as an oil reservoir, via lube oil circuit. The cooling water from the CCCW System is supplied to main lube oil cooler & working oil cooler and the mechanical seal water coolers across the each main BFP and Booster pump.

(c) High-pressure feedwater heater

The high-pressure system will have a total of eight feedwater heaters: two each in Nos. 6 to 8 and two in the desuperheaters, and these will be installed as two independent trains comprising one unit each in four stages. Each train will possess 50% capacity and be capable of operating independently so that it will be possible to conduct operation with a single train upon combining the 50% capacity bypass systems. For heating of the No.6 feedwater heater, extraction steam from the IP turbine and leak steam from the CV will be mixed and used after passing through the desuperheater. Part of the low-temperature reheat steam will be used for heating the No. 7 feedwater heater. For heating of the No.8 feedwater heater, extraction steam from the HP turbine and leak steam from the CV and OLV will be used.

9) Steam Extraction System

Table 5.2-5 shows the steam that will be used in each of the high-pressure and low-pressure feedwater heaters. Quick closing non return valves (QCNRV) will be installed on extraction steam lines leading to the high-pressure feedwater heaters, while for the No. 3 and No. 4 feedwater heaters, in addition to QCNRVs, isolating motor valves will be installed. Two numbers of QCNRVs will be installed going towards the deaerator.

Table 5.2-5 List of Steam Extraction

No.	Description	Application
1	No.1 extraction from HP section	HP heater 8A/B feedwater heating
2	No.2 extraction from CRH	HP heater 7A/B feedwater heating, Deaerator pegging heating steam
3	No. 3 extraction from IP section	HP heater 6A/B feedwater heating (through Desuperheater)
4	No. 4 extraction from IP section	Deaerator pegging / heating steam, Auxiliary Steam Header & TDBFP motive steam
5	No. 5 extraction from IP Section	LP heater 4 condensate water heating
6	No. 6 extraction from LP turbine (A) & (B)	LP heater 3 condensate water heating
7	No. 7 extraction from LP turbine (B)	LP heater 2 condensate water heating
8	No. 8 extraction from LP turbine (A)	LP heater 1 condensate water heating

10) Closed cycle cooling water system (CCCW system)

Each unit will be equipped with a closed cycle cooling water (CCCW) system that uses DM water, and these systems will be used to cool each item of auxiliary equipment. This system will be composed of pipes and tubes leading to each piece of equipment, CCCW heat exchanger, CCCW pump, DM water makeup system, and chemical dosing system. The CCCW heat exchanger will comprise three plate heat exchangers (one spare) with 50% capacity, and the CCCW pumps will comprise three centrifugal pump (one spare) also with 50% capacity. The warm water that has finished cooling will be returned and cooled in CCCW heat exchanger by the Auxiliary cooling water. The dosing will be manually controlled.

11) Auxiliary cooling water (ACW) system

The secondary side of CCCW system, Clarified Water will be used as cooling water. After this is taken from the condenser inlet, it will be pressurized by three cooling water booster pumps (one spare) with 50% capacity and passed through the CCCW heat exchanger. After passing through, the ACW will be returned to the condenser outlet. The system will have two 100% capacity automatic strainers (one spare unit), which will be controlled by the DCS together with the cooling water booster pumps.

(3) Generator

The generator's rated capacity will be 780 MVA, and its rated power factor will be 0.85 (Lag). Figure 5.2-9 shows the structural diagram of the generator.

This is a typical structure that has been repeatedly proven so far, and it reflects the technologies described below.

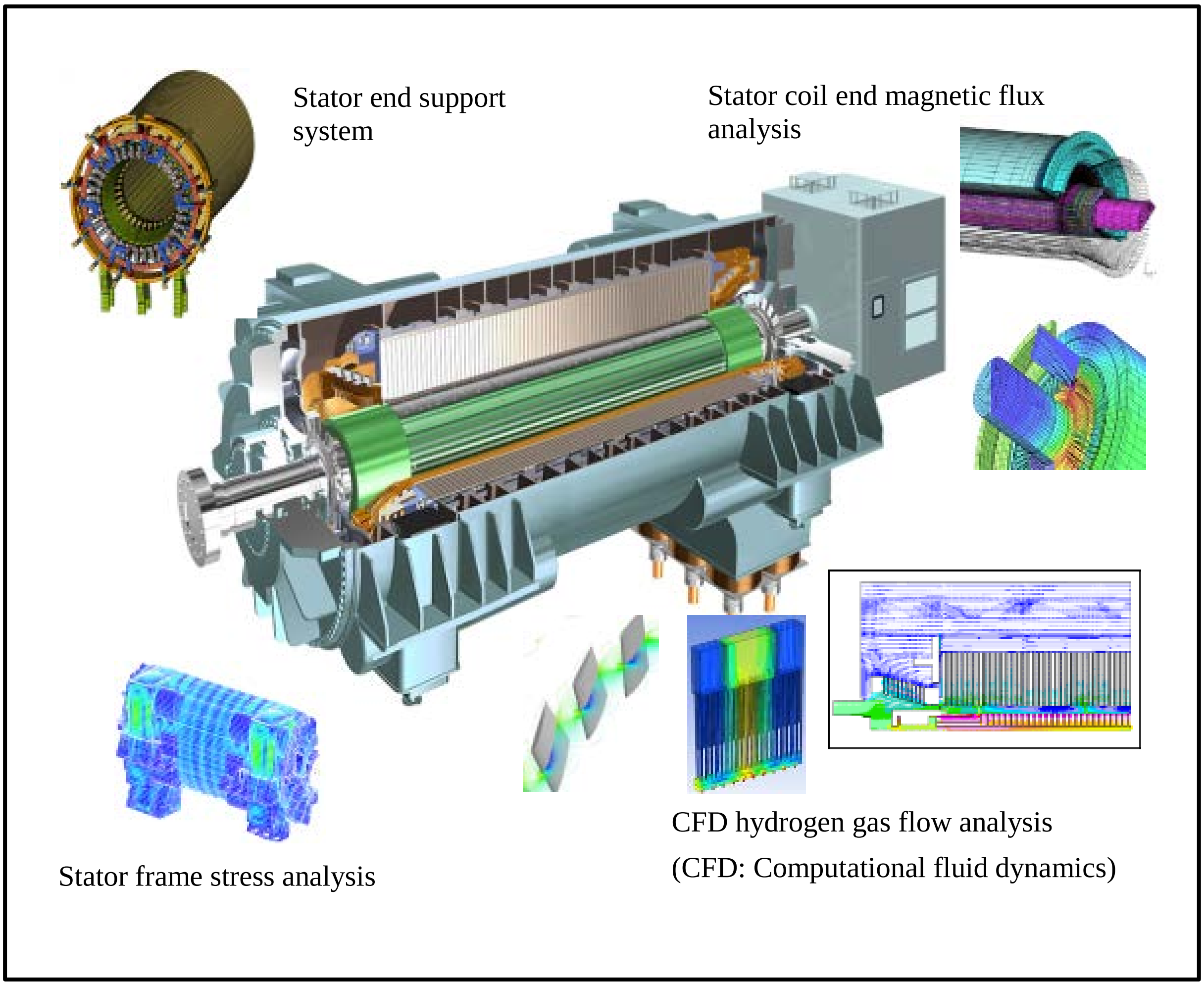


Figure 5.2-9 Generator Structure Diagram

1) Specifications

Table 5.2-6 shows the generator specifications.

Table 5.2-6 Example of Generator Specifications

Item	Specifications
Type	Three (3) phase, rotating field, Indoor, cylindrical rotor, synchronous Generator
Rated capacity	780 MVA
Frequency	50 Hz
Rated rotation speed	3,000 rpm
Terminal voltage	20,000 V to 27,000 V
Power factor	0.85(LAG)
Hydrogen pressure	0.52 MPa
Number of poles	2 poles

(4) Generator Auxiliary Equipment

1) Generator transformers

The generator transformers with rated capacity of 315 MVA/ phase will be installed per unit, and a further one main transformer will be installed as a common spare unit.

Table 5.2-7 Example of Main Transformer Specifications

Item	Specifications
Type	Single phase OFAF/ODAF cooling type
Rated capacity per phase	260 MVA
Quantity	3 transformers/unit + 1 common spare transformer
Voltage (primary / secondary)	$(420/\sqrt{3})$ / 20-27 kV
Coil (vector group)	YNd11
Type of tap changer	Off –load on HV side
Tap rang	±5% in steps of 2.5%
Applicable standard	IS2026 / IEC60076
Temperature rise with an Ambient of 50 ºC	Oil -40ºC Winding -45ºC

2) Exciter

Exciting systems come in various forms, however, the static excitation method that has been frequently adopted in recent years will be used here.

In terms of features, the static exciter has excellent responsiveness because it directly controls the generator field current; moreover, because there is no need to couple the exciter to the generator axis, it isn't affected by mechanical issues such as vibration and so on from the axis.

3) Cooler

For cooling of the generator rotors and stators, a direct cooling approach will be adopted whereby a hydrogen gas cooler, which utilizes hydrogen gas fed from the in-station gas feed system as the coolant, will be installed and hydrogen gas will directly pass through each conductor. Also, a cooling water system will be installed so that the stators are cooled by hydrogen gas and cooling water. As the water from the cooling water system will directly pass through the stator conductors, it is common for an ion exchange resin tower to be installed inside the cooling water system in order to secure the purity of water.

4) Seal oil system

Since hydrogen cooling will be adopted as the generator cooling system, it will be necessary to install a seal oil system in order to stop hydrogen inside the generator from leaking out. The seal oil system will comprise a main seal oil pump driven by an AC motor, an emergency seal oil pump driven by DC motor, a hydrogen separation tank, etc. In the case of a single flow system, since the hydrogen, air and water content will dissolve in the seal oil and spread through the generator causing the purity of hydrogen gas to diminish, it will be necessary to eliminate such impurities. Accordingly, it will be necessary to install a seal oil vacuum layer and vacuum pump in order to maintain the purity of the hydrogen gas, and it will be possible to keep the purity level high at 97-98%.

5) Generator circuit breaker

The generator circuit breaker will be connected between the generator and main transformer. At times of plant stoppage, the generator circuit breaker will "open" and in-station power will be supplied from the bus line of the in-station switchgear, via the generator transformer and unit transformer, to the high-voltage in-station bus line, making the starting transformer unnecessary. In addition, there will be the following merits:

- There will be no need for a bay to connect the starting transformer.
- There will be no need for high-speed switching to the starting transformer side when failure occurs in the station power.

5.2.3 River Water Supply System

The new power station will mainly use plant makeup water and condenser cooling water. Concerning the plant makeup water, it can be obtained through taking and purifying raw water from a nearby river, etc., or by desalinating seawater in the case where the power station is located on the coast. Concerning the condenser cooling water, water can be obtained from a river, etc. in the case of inland location, or seawater can be utilized in the case of coastal location. In the case of inland location, according to the newest controls by the MoEF (Ministry of Environment and Forests), a new thermal power station must use no more than 2.5 m^3/MWh (3,300 m^3/h in the case of a 2 × 660 MW power station) of raw water. Accordingly, it will not be possible to adopt a once-through condenser cooling system, and it will be necessary to conduct circulating operation upon installing a cooling tower. In this study, it is assumed that the power station is located inland.

(1) Raw water intake pump

The power station will obtain raw water via raw water intake pumps. These pumps, comprising three pumps (one spare) with 50% capacity, will be installed on a channel leading to the intake pit.

(2) Intake pit and channel

A channel will be installed from the river intake to the raw water intake pump installation point. Each RWI pump will be installed in an individual sump with provision to isolate for maintenance by stop log gates. Travelling water screen will be provided at the inlet of each pump sump.

(3) Intake water piping system

The obtained raw water will be conveyed via buried pipe to the raw water storage equipment. The piping system must be self-cleaned with existing flow but the velocities should not be excessive to cause erosion.

(4) Control room & switch gear room

A building for storing the local control panel and switchgears will be constructed adjacent to the raw water intake pump house.

5.2.4 Plant water system

Many power station construction sites in inland areas may have difficulty obtaining sufficient water from rivers during the dry season when rainfall is low. Accordingly, the new power station here will be equipped with raw water storage tanks having sufficient capacity in consideration of the maximum usage of makeup water and the estimated period of low intake.

In the pretreatment system that includes clarifier, clarified water will be manufactured for various purposes in the power station. The clarified water manufacturing capacity will be 120% of the maximum water usage of the power station. The manufactured clarified water will be stored in a clarified water tank.

The demineralization system will produce DM water from clarified water, and it will have sufficient capacity to meet the demand for system makeup water (1.5% of the BMCR main steam flow), CCCW makeup water, CPU regenerating water and other water. The tank for holding the manufactured DM water will have enough capacity to hold one day's supply.

(1) Examination of diversion

In the case where the existing power station is replaced, it is sometimes possible to reduce construction costs through diverting the existing water treatment system for use in the new power station. However, when examining the feasibility of diversion, it is necessary to carefully consider whether or not the performance requirements of the new power station are consistent with the specifications and performance of the existing equipment. It is also necessary to consider the remaining service life of the existing water treatment system.

(2) Main cooling water (MCW) system

At the new power station, as a result of the aforementioned MoEF controls, the river intake flow will be limited. Accordingly, it will be necessary to circulate the main cooling water (MCW) for between the condensers and the cooling towers. In order to prevent corrosion of the thin tubes inside the condensers, the raw water will first undergo clarification for reducing suspended solids before it is used as the main cooling water.

Each unit will be equipped with two MCW pumps of 50% capacity, and there will be no spare units. However, in the case where one of the pumps breaks down, it is possible that continuous operation at rated load will be conducted with reduced condenser vacuum triggered by the reduction in cooling water flow. The cooling water circulated by the MCW pump will undergo filtration by a side stream filter (SSF) and it will be dosed with chlorine, anti-scalant and biocide for prevention of pipe corrosion and bio-fouling. As the MCW pumps, vertical fixed speed pumps will be adopted, and the cooling water will be circulated via pipes connected to the condenser inlets and outlets. Blowing will be implemented at the MCW pump outlet, and the low water will be sent to the wastewater treatment system. Clarified water will be utilized for replenishment. EOT crane and Stop log gates are provided for maintenance and/or repair works. The screens will be provided to prevent foreign material viz. debris etc. entering into the MCW pump. The MCW pumps will be operated / controlled from the DCS.

(3) Cooling tower

The waste heat that is moved to the main cooling water in the condensers and the waste heat from auxiliary equipment recovered on the main cooling water side by the CCCW heat exchanger will be discharged into the atmosphere via the cooling tower. In the project site where the summer air temperature is high, it will be desirable to adopt an open type cooling tower for greater cooling effect. This will bring the cooling water into direct contact with the atmosphere in order to discharge heat through evaporation. In line with the evaporation of cooling water into the atmosphere, because the impurities in the cooling water will become thicker, the appropriate thickness will be sustained through conducting blow-down operation for replenishing the cooling water that is removed from the system. The ventilation system can either be a forced ventilation or a natural ventilation system, and it will be necessary to select the most appropriate type according to the limitations on site area, etc. The forced ventilation system has the merits of being more compact and having more stable performance, and it is appropriate for introduction to sites where existing power stations are replaced and the site area is limited. The water tank underneath the cooling tower will have sufficient capacity to enable 10 minutes of operation from the normal water level to the low water level.

(4) Water treatment system

There are cases where rivers that provide the raw water for inland power stations have poor water quality due to the inflow of household wastewater, etc. In the study here, the equipment configuration was examined assuming the case where the raw water quality is poor. As an example of intake water quality for a new power station, Table 5.2-8 shows the quality of water in Agra Canal, which is the intake source for Badapur Power Station. This canal is used as a drainage channel for household wastewater, and the water quality has deteriorated in line with the economic development of the surrounding area in recent years. In reality, depending on the quality of river water around power station construction locations, the equipment configuration can be simplified. The raw water for use in the power station will be conveyed from the raw water storage tank by conveyance pump. Similarly, the raw water that will be used in ash treatment equipment will be sent from the raw water storage tank by ash treatment makeup water pump. At the power station, the raw water will undergo clarification in the pretreatment system, and the manufactured clarified water will be utilized for the following purposes:

- Cooling tower makeup water
- Plant service water
- Feedwater for the RO-DM plant and potable water
- Water for fire extinguishing
- Seal Water for Ash Handling Plant (AHP)
- HVAC makeup water
- Air preheater and electrostatic precipitator (ESP) washing water
- Flue gas desulfurization (FGD) system makeup water

Table 5.2-8 Example of Raw Water Quality

S. No.	Item	Raw water measurements (Low side values are observed in the rainy season only)	Design water quality
1	Conductivity, μs/cm	1,000 - 2,500*	1,300
2	pH	7.0 - 8.0	-
3	Calcium Hardness, mg/l as $CaCO_3$	70 - 280	300
4	Magnesium Hardness, mg/l as $CaCO_3$	50 - 190*	64
5	Total Hardness, mg/l as $CaCO_3$	120 - 470*	265
6	Sodium & Potassium, mg/l as $CaCO_3$	140 - 784*	312
7	Total Cations, mg/l as $CaCO_3$	260 - 1,254*	676
8	M-Alkalinity, mg/l as $CaCO_3$	140 - 552*	363
9	Sulphate, mg/l as $CaCO_3$	20 - 148*	97
10	Chloride, mg/l as $CaCO_3$	90 - 554*	216
11	Total Anion, mg/l as $CaCO_3$	260 - 1,254*	676
12	Fe as Fe, mg/l	0.2* - 0.6*	0.1
13	Silica as SiO_2, mg/l	12 - 33.6*	13.9
14	BOD, mg/l	30 - 60	-
15	COD, mg/l	50 - 140	-
16	TOC, mg/l	25 - 43.4	-
17	Total Kjeldhal Nitrogen, mg/l as N	10 - 25 mg/l	-
18	Total Sulphide, mg/l as S	5	-
19	Total Phosphorous, mg/l as PO_4	8	-
20	Turbidity (NTU)	60 - 950	-

Figures followed by * are in excess of design values.

The sludge that is generated in the pretreatment system will be treated in the wastewater treatment system.

The clarified water system will pass through an RO membrane and mixed bed polisher (MBP) and become DM water. The RO membrane will be designed to ensure that the water will comply with the standard for potable water after passing through. The manufactured DM water will be used as plant makeup water, CCCW makeup water and CPU regenerative water, and for dissolving chemicals and so on.

Before the DM system, a dual media filtration system for reducing turbidity and total suspended solids, and an active carbon filter (ACF) for reducing organic matter will be installed. Moreover, behind these suspended matter will be removed by means of a basket filter and ultrafiltration (UF) membrane.

After passing through the UF membrane, the water will be pumped through the RO membrane for desalination. After the water passes through the RO membrane, dissolved carbon dioxide will be removed in the deaeration tower and some of the water will be used as potable water.

The MBP will be filled with a mixture of positive ion exchange resin and negative ion exchange resin for eliminating any residual salts in water that has passed through the RO membrane.

The manufactured DM water will be stored in a pure water tank large enough to hold a 24-hour supply.

The resin regeneration chemical tanks will be large enough to hold a 30-day supply. After the wastewater from regeneration has been neutralized in the neutralizing tank, it will be recovered in the wastewater treatment system. The thickened water generated from the RO membrane will be used for transporting ash.

The pretreatment and water purification system will be controlled by the PLC (Programmable Logic Controller) with the necessary signals being exchanged with the plant DCS.

5.2.5 Wastewater treatment system

In line with the fact that the latest controls by the MoEF have made it impossible to discharge wastewater outside of thermal power stations and limit the river raw water intake volume to 2.5 m^3/MWh, the wastewater that is generated in each system of the new power station will be treated and recycled in a wastewater treatment system. However, concerning rainwater, since it is possible to discharge upon taking steps to prevent mixing with other wastewater, this will not be included in the wastewater treatment system. The wastewater treatment system will have functions for separating oil, neutralizing, removing suspended solids and removing dissolved solids.

Wastewater from the various areas of the plant will be recovered in a Central monitoring Basin (CMB), which will have the function of regulating the amount of wastewater flowing into the wastewater clarifier behind it. In the wastewater clarifier, the turbidity and total suspended solids of wastewater will be reduced, and the water will be stored in the wastewater clarified water storage tank. The wastewater clarified water will be used in the coal conveying system and coal treatment system, and excess water will be pumped to the DMFs.

The DMFs will remove suspended solids from the sedimentation effluent and send the filtered water to the following ultrafiltration unit. Filtrate from the DMFs will undergo further filtration in the basket filter and UF unit, after which it will be stored in the UF permeate tank. Filtrate sent from the UF permeate tank will be pumped to the RO membrane. After passing through the RO membrane, water will be replenished in the clarified water tank of the makeup water treatment system, and the thickened water that is generated will be used for ash transportation. The wastewater treatment system will be controlled by the PLC with the necessary signals being exchanged with the plant DCS.

(1) DM and CPU regeneration waste water

In the CPU and DM plant, acid and alkali chemicals will be used to regenerate the ion exchange resin. The regeneration wastewater that includes these chemicals, and the water purification system RO membrane wash water that includes highly concentrated salts will be transferred to the CMB following PH regulation in the neutralizing tank.

(2) Cooling tower blow-down water

The cooling tower blow-down will be needed in order to suppress the dissolved solids content of the main cooling water. This effluent will contain TDS, chemicals of biocides used for prevention of scale formation, corrosion, bio fouling etc. The complete CT blowdown will be routed to the ash slurry sump.

(3) SSF reverse wash water

The SSF backwash water will be collected in a pit and transferred to the CMB.

(4) Sludge handling system

The sludge handling system will handle sludge that has been generated in the pretreatment and wastewater treatment clarifier. The sludge that settles at the bottom of the clarifiers will be recovered by sludge pump and transferred to the sludge handling system. Comprising thickener and centrifuge, the sludge handling system will solidify the sludge. The recovered water from the sludge handling system will be collected and transferred to the CMB.

(5) Quenched boiler blowdown recycling system

In the new power station that adopts USC, boiler wastewater will not be generated all the time. When it does arise, it will be reduced in temperature to around 60°C through mixing with clarified water and transferred to the CMB.

(6) Oil handling area effluent & service oily waste

The oily water from plant area will be treated in oily waste treatment system. The oil contaminated water will be collected to an oily waste collection pit and will be pumped to Oil Water Separator (OWS) of TPI type for removal of free floating oil. The treated water from OWS of TPI type will be pumped finally into ash slurry sump.

5.2.6 Electric Equipment

(1) Main electric equipment

1) Transformers (in-station)

Transformers will be installed between the generator transformer and generator circuit breaker and high-voltage station bus in order to step-down the generator output voltage from 20-27 kV to 11 kV so that power can be supplied to the power station. Two transformers will be installed to ensure that the station power system is not greatly affected even when failure occurs; moreover, impacts on the plant will be kept to a minimum through dispersing auxiliary units around each bus line connected to the transformers.

Also, an 11/3.3 kV transformer will be installed to supply power.

2) Emergency power supply

Emergency power supply equipment will comprise storage batteries for supplying power to emergency oil pumps for preventing burning in seal oil pumps and turbines for preventing hydrogen gas leaks and stopping damage to emergency lighting and equipment for securing the safety of employees at times of power failure in the power station. In addition, there will be an emergency generator and uninterrupted power supply for use as AC power sources.

3) Emergency generator

An emergency generator will be installed in order to supply the minimum required power for equipment maintenance at times of power failure in the plant. Usually light oil is used as the fuel.

4) UPS (uninterrupted power supply)

AC power supply at times of power failure will be supplied from the emergency generator, however, because a certain amount of time is required until completion of emergency generator start, AC power supply is lost during this period. Moreover, because there is a risk that voltage and frequency fluctuations could have an impact on equipment operation, UPS will be installed to avert this and AC power will be supplied upon using an orthogonal transformer to convert output from a dedicated battery to an AC power supply of stable voltage and frequency even at times of power failure in the plant. At normal times, AC power supply on the upper side will be converted to DC by the orthogonal transformer in order to charge the storage battery.

5) Switchgear equipment (high-voltage, low-voltage)

The circuit breakers connected on the high-voltage in-station bus will be VCB, and the low-voltage side will be ACB and MCC.

Each circuit breaker including the bus will be stored inside housing to prevent live parts being touched from outside; moreover, air-tightness will be maintained to prevent dust and other foreign materials from infiltrating the equipment and causing short circuits, etc.

(2) In-station electricity system

1) Bus connection

All bus lines inside the station will be duplexed in order to enhance safety and plant reliability. Bus connection circuit breakers will be connected between duplexed buses, and in cases where a circuit breaker connected to a bus is switched “Off” in order to isolate the failure point in the event of transformer failure, etc., the bus connection circuit breaker will be turned “On” to prevent power interruption on the bus line.

2) Configuration

Configuration of the in-station electricity system will be high-voltage bus being 11 kV and the low-voltage side being 3.3 kV. Concerning power supply to outdoor equipment such as coal loading and conveyance equipment, ash treatment equipment, water intake equipment and desulfurization system, power will be supplied as 11 kV due to the long distances from the turbine building; then it will be stepped down for use as 3.3 kV inside switchgear equipment of the coal handing plant and ash handling plant, etc., thereby mitigating electrical loss.

(3) Switchyard Equipment

Concerning draw voltage from the power station, 220 kV or 400 kV is envisaged. In reality it will be necessary to predict the future power flow from the conditions of power transmission, substation and estimated power demand, etc. around the power station in future. Since the power station here will be constructed on the outskirts, assuming that power will be transmitted long distances to the city, the 400 kV system that entails lower transmission loss will be adopted.

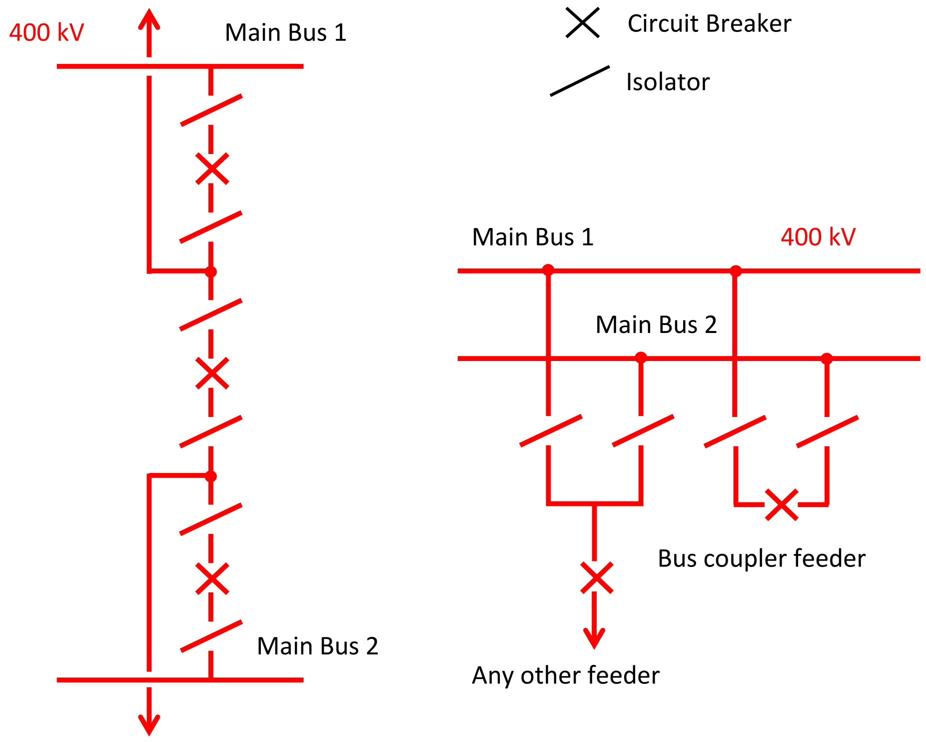
1) Switchyard

Two 400 kV D/C lines will be drawn out from this switchyard in order to correspond to LILO (Loop-in Loop-out) connection.

Inside the switchyard, a control room will be constructed and equipped with remote control and protective devices, and telecommunications equipment based on the SCADA (Supervisory Control and Data Acquisition) will be installed.

Through comprising a full GIS (Gas Insulated Switchgear) system, that includes circuit breakers, disconnectors and other auxiliary equipment, live parts will be covered and it will become possible to safely conduct work even when maintenance is being conducted nearby.

According to CEA guidelines in India, the bus system is determined according to the bus voltage and type of insulation in used circuit breakers. In cases where GIS is installed in a 400 kV switchyard, the guidelines stipulate the (i) 1+1/2 bus scheme and (ii) double bus scheme. The two schemes are illustrated in Figure 5.2-10.

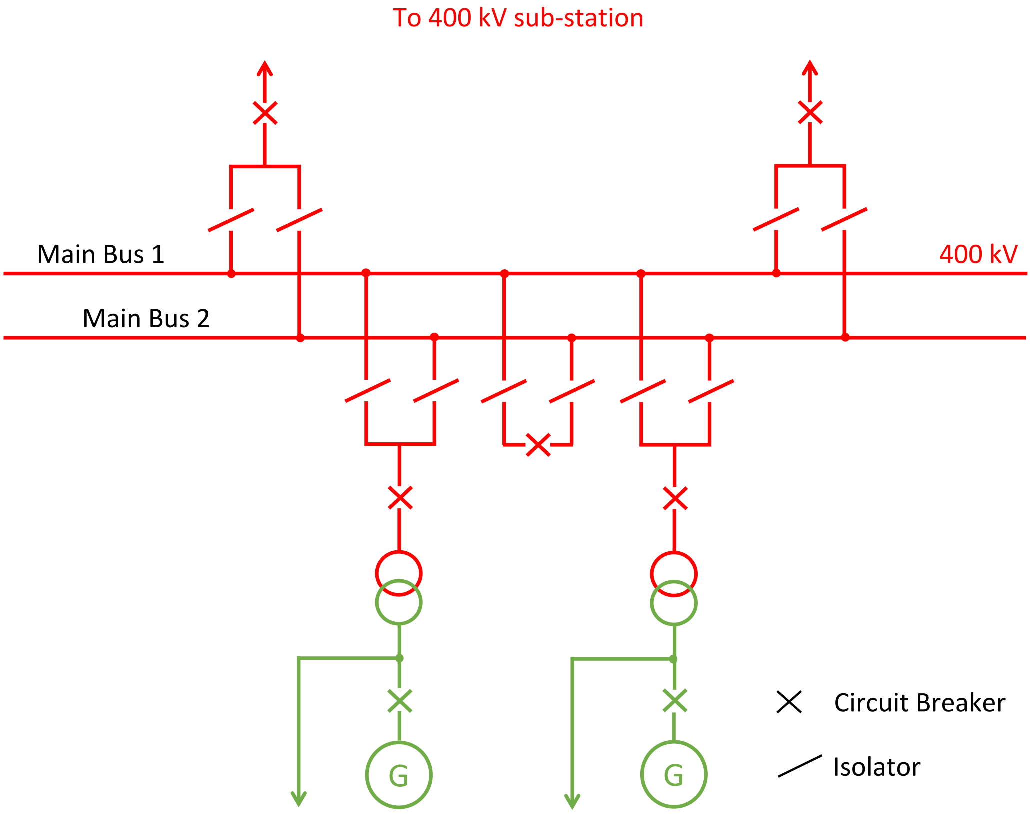


【(i) Breaker and a half scheme】 【(ii) Double bus scheme】

Comparision of Configuration Scheme

Figure 5.2-10 Bus Configuration (Examples)

Figure 5.2-11 shows the case where two 660 MW units are installed and the double bus scheme is adopted.



Configuration image (Double bus scheme)

Figure 5.2-11 Single Wire Circuit Diagram of Switching Equipment (Example)

Since the GMCB (Generator Main Circuit Breaker) system will be adopted, installation of a starting transformer will not be considered.

Moreover, when conducting the actual design, it will be necessary to secure the necessary site area in consideration of transformation equipment (400 kV/220 kV) and reactors inside the switchyard and spare connection points in readiness for future expansion.

2) GIS(Gas Insulated Switchgear)

Since SF6, which has a high heating coefficient, is usually used as the arc extinguishing gas in the GIS being considered for installation here, it will be desirable to introduce products that minimize gas leakage in order to limit discharge of greenhouse gases.

3) ICT (Inter Connected Transformer)

It is desirable to install ICT for enhanced stability when there is 220 kV switching equipment, however, this should be in compliance with IS2026 and IEC60076.

Basic items upon examining the layout of GIS switching equipment are as follows.

Examination of Basic Layout

- Location Conditions
  - Minimization of interior capacity
    - Increase of occupation ratio within the building capacity
    - Reduction of space considering installation, inspections and troubleshooting
    - Standardization of building design
  - Minimization of outdoor space
    - Reduction of space upon generally considering position of power line draw-out positions, layout of transformers and other equipment, future expansion plans, etc.
    - Consideration of space for cranes and other heavy equipment in consideration of equipment disassembly and dismantling
- System conditions
  - Selection of phase-separated, three-phase package type
    - The three-phase package type will be the basic scheme, however, phase separation will be selected for greater system stability when internal failure arises in the three-phase bus
- Structural simplification
  - Simplification of structure and frames
    - Frameless structure and simplification of patrol corridor and operating structure
- Ease of operation and maintenance
  - Aim for maintenance-free design and strive to minimize the scope of stoppage at times of inspection and maintenance and to facilitate inspection work (labor saving in patrol and monitoring work)
    - Minimization of stop time and scope when conducting expansion
    - Unification of operating positions
    - Fixed position work when inspecting switchgear (circuit breakers, disconnectors, installation switches
    - Simplification and unification of monitoring contents
- Troubleshooting
  - Minimization of stoppage scope and securing of work safety when trouble
    - Isolate stoppages in the event of troubleshooting and inspections to 1 line and 1 bus (equipment and gas)
    - In equipment assembly and dismantling work when recovering from failures, setting of work switch positions, gas divisions and equipment layout in consideration of prevention of induction, steps to address reduced gas pressure adjacent to work areas and other safety measures
- Economy
  - In addition to minimizing bus over the entire GIS switchgear, strive for overall economy including frames and foundations.

Since the full GIS that is covered up to the bus will have no exposed live parts and be resistant to external impacts, it is maintenance-free equipment with high reliability: On the other hand, in the event of internal failure, since the equipment comprises a closed, compound integrated unit, it will take a long time to recover and it will be extremely important to control time and foreign objects in the manufacturing and installation processes.

5.2.7 Instrumentation and Control System

(1) Control system for once-through boiler

In once-through boilers, unlike drum boilers, the evaporation completion point differs according to conditions. This means that single elements (operating ends) such as fuel, feed water, etc. have an impact on control of other elements.

For example, in the case where the feed water flow rate is increased, in the case of drum boilers, only the drum water level rises, however, in once-through boilers, because the evaporation completion point moves downstream, the main steam temperature is directly reduced. Accordingly, when increasing the feed water flow rate, it is necessary to simultaneously increase the fuel flow rate. In once-through boilers, the main steam temperature is controlled by the water-fuel ratio while spray control serves an auxiliary role unlike that of the drum boiler.

In this manner, fluctuations in the control system of a once-through boiler including external disturbances directly impart a major impact on plant operation.

(2) Basic operation and monitoring policy

- It will be made possible to conduct normal operation control and start/stop operation from the central control room with the minimum personnel. Concerning local equipment such as coal handing plant and Flue gas desulfurization, etc. separate control rooms will be installed for operation and monitoring.
- Plant information will be consolidated in the central control room, where the monitoring console will make it possible to conduct intensive management and it will be install a data log system for monitoring trends and analyzing failures when troubles arise.

(3) Plant automation

1) Start and stop times

When starting and stopping the plant, automation will be adopted including in the following starting and stopping processes.

Break points will be installed between each process, enabling operators to advance processes after confirming progress.

(a) Start time

(Example) Circulating water system start → Condensate system start → Boiler ignition preparation → Boiler ignition → Turbine start → Parallel in → Increased load

(b) Stop time

(Example) Reduced load → Parallel off → Boiler extinguishing → Condensate system stoppage → Seawater system stoppage

2) During normal operation

During normal operation of the plant, commands will be received from the load dispatching office, output settings will be changed and output will be controlled based on a parallel control mode of the boilers and turbines.

In addition to the boiler and turbine parallel control mode, there are boiler follow and turbine follow modes, each possessing the features described below.

(a) Boiler follow mode

In this mode, the turbine governor reacts first to output commands and changes input on the boiler side so as to compensate for fluctuations in main steam pressure. This system enables fast output response, however, it takes time for the boiler side to reach a stable point.

(b) Turbine follow mode

In this mode, in response to input changes on the boiler side, fluctuations in main steam pressure are compensated by the turbine governor. Although the boiler becomes stabilized, the output response is slow.

(c) Boiler-turbine parallel control mode

The boiler-turbine parallel control mode combines the features of the two systems above. Since the turbine governor and boiler input flow are controlled in response to output commands, the output response is fast and the time taken for the boiler side to stabilize is short; consequently, this system is widely adopted in large-capacity thermal power stations.

3) Security system test

At times of abnormality in the plant, since it is important for important items of equipment to certainly operate, the following tests will be implemented in order to confirm that operation is sure at times of normal operation too.

(Example)

- Main stop valves opening/closing test
- Oil pump automatic start test
- Over speed trip test

(4) Plant interlock

In cases where the plant cannot be stably operated or there is an accident that could cause damage to equipment, it will be necessary to quickly stop the plant. Accordingly, a plant interlock system will be installed in order to protect the overall plant.

Table 5.2-9 Plant Interlock Items (Example)

Equipment	Trip Item
Boiler	• Flame loss • Main steam pressure high • Boiler feed water flow - low, etc.
Turbine	• Turbine vibration - high • Turbine bearings oil pressure - low • Turbine thrust transfer - high
Generator	• Generator grounding • Generator over-voltage • Generator field loss
Transmission line	• Transmission line trip • Bus shorting • Transfer trip

(5) Policy of redundancy

The basic policy of redundancy in the control system configuration is described below, however, since redundancy causes the design cost and equipment cost to fluctuate, it will be necessary to differentiate redundancy according to importance.

1) Control system power source

Power for the control system will be supplied as both AC and DC to ensure that the control system does not stop even at times of power interruption. Moreover, batteries will be separately equipped to ensure that data in the memory is not deleted.

2) Control system (CPU, etc.)

The control system will be multiplexed to ensure that there are no signal disparities and enable bumpless switching even when the CPU and network stop. The use rate of the redundant CPU must be designed never to reach 100%.

3) Detectors

Detectors are broadly divided into three types: those for protection, those for control, and those for monitoring.

- Protective detectors will be triplexed, and two out of three of the protective circuits will be configurable.
- Control detectors will be duplexed. When signal disparities arise, signals will be maintained to ensure they don't cause malfunction and to maintain the plant condition at that time.
- Since monitoring detectors will have no direct impact, they will be single configuration in order to limit costs.

In cases where detector tubes become blocked by foreign materials, since it is possible that detectors will not show normal values, it will be necessary to examine multiplexing the detection lines in such places not including the single configurations.

(6) Alarm system

The alarm system will be subject to centralized control by DCS from the operation station in the central control room, and information from local control rooms will also be sent to the central control room by DCS.

Generated alarms will be displayed in chronological order, but it will be possible for operators to filter them according to level and category and thereby easily grasp abnormal conditions in the plant.

Alarm history including event information will be stored for a certain period of time, and operators will be able to extract information optionally within the time frame they desire.

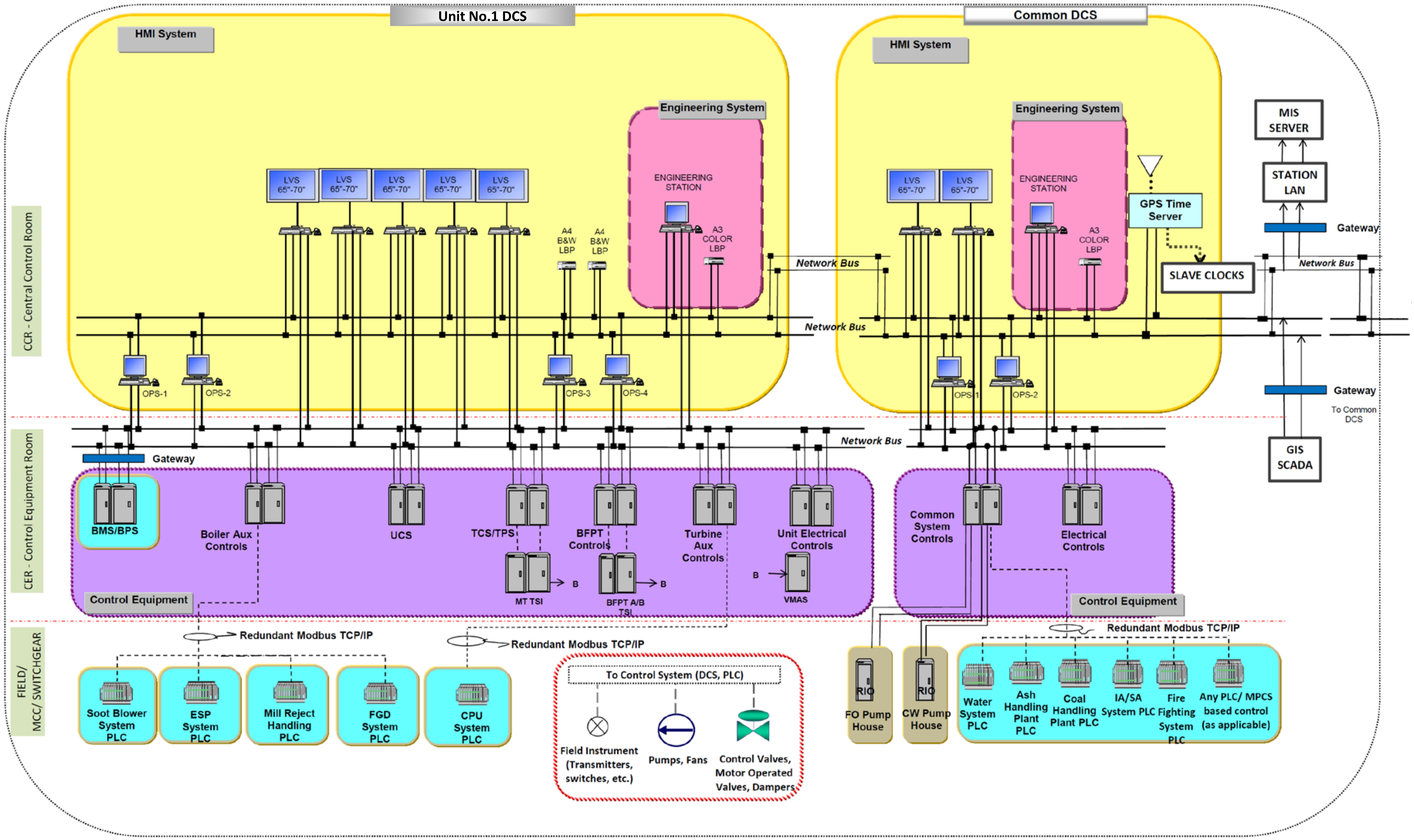
(7) Configuration of control systems

The system configuration will include Unit Nos. 1/2 and common sections and control will be conducted from the central control room, control rooms and local control rooms.

The control system installed at the heart of the central control room will be connected to the OPS (Operator Station) in the central control room via the network and be controlled by operators.

Concerning the power station switchyard, SCADA (Supervisory Control and Data Acquisition) system will be adopted and control, measurement, protection, monitoring and communications will be conducted from the central control room.

Figure 5.2-12 shows the control system configuration.



Unit & BOP DCS Description
UCS: Unit Coordination & Boiler Modulating Control System
TCS: Turbine Control System
TPS: Turbine Protection System
MPCS: Manufacturer's Proprietory Control System
GPS : Global Positioning System
R I/O: Remote Input/Output Cubicle

System Description
TSI: Turbine Supervisory Instrumentation

HMI Description
LVS : Large Video Screen
OPS: Operator Station
Color LBP: Color Laser Beam Printer
B/W LBP: Black & white Laser Beam Printer
A-Network: Administration Network

Central Control Room
Engineering Room
Equipment Room
Local Control Room
By Others

Figure 5.2-12 Control System Configuration Diagram

5.2.8 Instrumentation Equipment and Control Systems

(1) Electronic transmitters (pressure / different pressure / flow / level / temperature)

The process values from the thermal power station feed water and steam system, fuel system, air system, etc. will be used for controlling and monitoring processes in plant operation. Pressure and differential pressure transmitters that possess silicon resonant sensors will measure pressure, differential pressure, flow rate and level, while temperature sensors will measure process temperatures.

(2) Continuous Air Emission Monitoring System (CEMS)

In order to monitor the condition of fuel combustion, improve combustion efficiency and conduct monitoring of harmful substances in exhaust gases with the goal of environmental conservation, an exhaust gas analyzer will be installed to measure the constituents of exhaust gases. Measurements will target exhaust gas components such as sulfur oxides (SOx), nitrogen oxides (NOx), oxygen (O_2), carbon monoxide (CO) and dust.

(3) Distributed Control System (DCS)

In order to conduct continuous control and monitoring and efficient maintenance of power stations, DCS is introduced. Since this is extremely important plant equipment classified as a main power supply, it is necessary to examine introduction that realizes stable operation and considers continuing use. Accordingly, it is recommended that DCS that satisfies the following requirements be introduced.

- Reliability that guarantees operating rate of 99.99999%
- CPU having Pair & Spare design
- Redundancy control bus that possesses transmission speed of 1 Gbps
- Bumpless switching with redundancy circuit of less than 1 msec
- Unique redundancy function in the CPU and I/O module
- Outstanding maintainability based on system succession and compatibility, and a long-term support setup

(4) Simulator

The plant simulator will be introduced with the objective of adequately improving the operating technique of operating personnel prior to the start of commercial operation. In addition to the reliability and performance of equipment, stable operations based on the skill and experience of operators are essential for operation of a coal-fired thermal power plant.

It is effective to introduce a simulator in order to train operators and raise their skill to adequate levels before the start of commercial operation. Moreover, a simulator can be used for training after the start of operation too. The simulator configuration is broadly composed of the plant model, DCS operation monitoring system possessing virtual operating function, and simulator setting system. Because the plant model will be created by veteran engineers based on actual process dynamic characteristics, and the DCS control logic will be connected to the plant model via a gateway, it will be possible to conduct training in an environment almost identical to real conditions.

This plant model based on the actual plant can be used to simulate plant starting and stopping, optionally raise load, and make settings according to requirements. Moreover, through simulating process conditions in optionally selected abnormal cases, it also makes it possible to train operators to deal with abnormalities that may occur in actual plant operation.

(5) Steam and Water Analysis System (SWAS)

This system is an analyzer for managing the condition and quality of boiler feed water and steam and preventing corrosion damage in the power station instruments and equipment. The following components are measured: PH, conductivity, hydrazine, silica, sodium ion, dissolved oxygen, chloride, phosphate, turbidity, etc. Usually a single company becomes the integrator and supplies the system.

(6) Ambient Air Quality Monitoring Station (AAQMS)

This system is intended to monitor the ambient air around the power station for the objective of environmental conservation, etc.

The condition of ambient air is constantly monitored through monitoring the following items around the power station: sulfur oxides (SOx), nitrogen oxides (NOx), oxygen (O_2), carbon dioxide (CO_2), suspended particulate matter (SPM), wind velocity, wind direction, air temperature, humidity, rainfall, etc.

(7) Vibration Monitoring System (VMS)

This system measures vibration in the turbine and other rotating machines and conducts continuous monitoring to ensure normal operation. When the vibration increases, since there is a risk of major accidents such as breakage of rotating machines occurring, this is an important measurement item.

(8) Closed Circuit Television (CCTV)

Because a thermal power station possesses numerous items of equipment spread out over a wide area, this system will be installed in order to conduct remote monitoring of the entire complex. Cameras will be installed in each area, and the images from each area will be monitored on monitors installed in the central control room and other desired locations.

(9) Operation Efficiency Improvement Package

The operation efficiency improvement package is an operation support system linked to the DCS. Based on the operating know-how of skilled operators, through standardizing and automating procedures for start and stop and blow-down operations and so on when fluctuations arise in the operating quality, this package improves operating efficiency and realizes the sharing and passing-on of technical know-how.

5.2.9 Coal Handling and Storage Facility

(1) Coal Handling Plant

1. CHP consists of two (2) parallel & identical stream rated at 1848 tph capacity [each] commencing from Wagon Tippler Complex and terminating at Bunker Feeding Conveyor # BC-8A/8B located on top of Coal Bunkers of Unit-1/2 .
   Layout plan & Flow diagram of CHP is enclosed as Annexure – 1.0 & 2.0.
2. Coal will be unloaded by two (2) no. Tandem Tippler # TWT-1A/1B. Using conveyor # BC-2A/2B & BC-3A/3B, coal will be stockpiled into coal stockpile # CCS-1/2/3/4 by means of operating Stacker-cum Reclaimer Machine # SR-1A/1B having unidirectional Yard Belt Conveyor # YBC-1A/1B.
3. Stockpiles # CCS-1/2/3/4 shall be covered by Shed # SHD-1/SHD-2 to prevent wetting of coal due to rain during rainy season.
4. Coal unloaded by Tippler # TWT-1A/1B, can be sent directly from Wagon Tippler Complex to Coal Bunkers of Unit – 1 & 2 using connected conveyor system i.e. Conveyor # BC-1A/1B, BC-2C/2D, BC-5A/5B, BC-6A/6B, BC-7A/7B & bunker feeding Conveyor # BC-8A/8B provided with Plow Scrapers to discharge coal into various Bunkers.
5. In case, coal rakes do not arrive at Wagon Tippler Complex of Power Station, then coal will be reclaimed by Bucket wheel type Stacker cum Reclaimer M/C # SR-1A/1B and fed onto Yard Belt Conveyor # YBC-1A/1B and subsequently delivered to Coal Bunkers of Unit -1 & 2 using connected conveyor system as noted above.
6. Alternatively, coal can also be delivered from Wagon Tippler Complex to Coal Bunkers via Conveyor # BC-2A/2B/3A/3B and Yard Belt Conveyor # YBC-1A/1B using stockpile by pass facility of Stacker-cum Reclaimer M/C # SR-1A/1B.
7. In the vicinity of stockpile#CCS-4, One (1) Reclaim Hopper Complex# ERH-1 with six (6) underground RCC hoppers # RH-1/2/3/4/5/6 are provided. During emergency, Coal will be dozed by dozers from Stockpile # CCS- 4 and fed into these underground reclaim hoppers which in turn will feed crushed coal onto Conv # RC-1 using Vibrating Feeders # VF-1/2/3/4/5/6. Conveyor # RC-1 in turn will feed coal onto Conveyor # BC-4A/4B. Conv # BC-4A/4B will deliver crushed coal to Coal Bunkers via connected conveyors system as noted above.

8. Thus coal can be fed to coal bunkers using following routes:

   1) From Wagon Tippler Complex to Coal Bunkers Of Unit-1&2 using Conveyor # 2C/2D and connected Conveyor System including Bunker Filling Conveyor # BC-8A/8B.
   2) Wagon Tippler complex to Coal Bunkers using Conveyor # BC-2A/2B, Yard Belt Conveyor # YBC-1A/1B (using stockpile by pass facility of Machine#SR-1A/1B) AND connected Conveyor System including Bunker Filling Conveyor # BC-8A/8B.
   3) From stockpile # CCS-1//2/3/4 to Coal Bunkers, using M/C # SR-1A/1B, yard belt # YBC-1A/1B & connected Conveyor System including Bunker Filling Conveyor # BC-8A/8B.
   4) From Crushed Coal Stockpile # CCS-4, coal will be delivered to Coal Bunkers via dozers/ ERH-1/ Vibrating Feeders/ Conv#RC-1/ conv # BC-4A/4B & connected Conveyor System including Bunker Filling Conveyor # 8A/8B.

9. CHP shall be complete with Auxiliary System / Equipment such as Coal Sampling System, Tunnel Ventilation System, Cold Fog Dust Suppression System[to control dust nuisance at transfer points] ,Inline Magnetic Separator ,Suspended Electromagnet ,Belt Weighers ,Metal Detectors ,Electric Hoists & Manual Hoists(for equipment maintenance),Sump Pumps ,Bull Dozers ,Front End Loaders etc. Ovearall flow diagram is indicated in the following Figure 5.2-13.

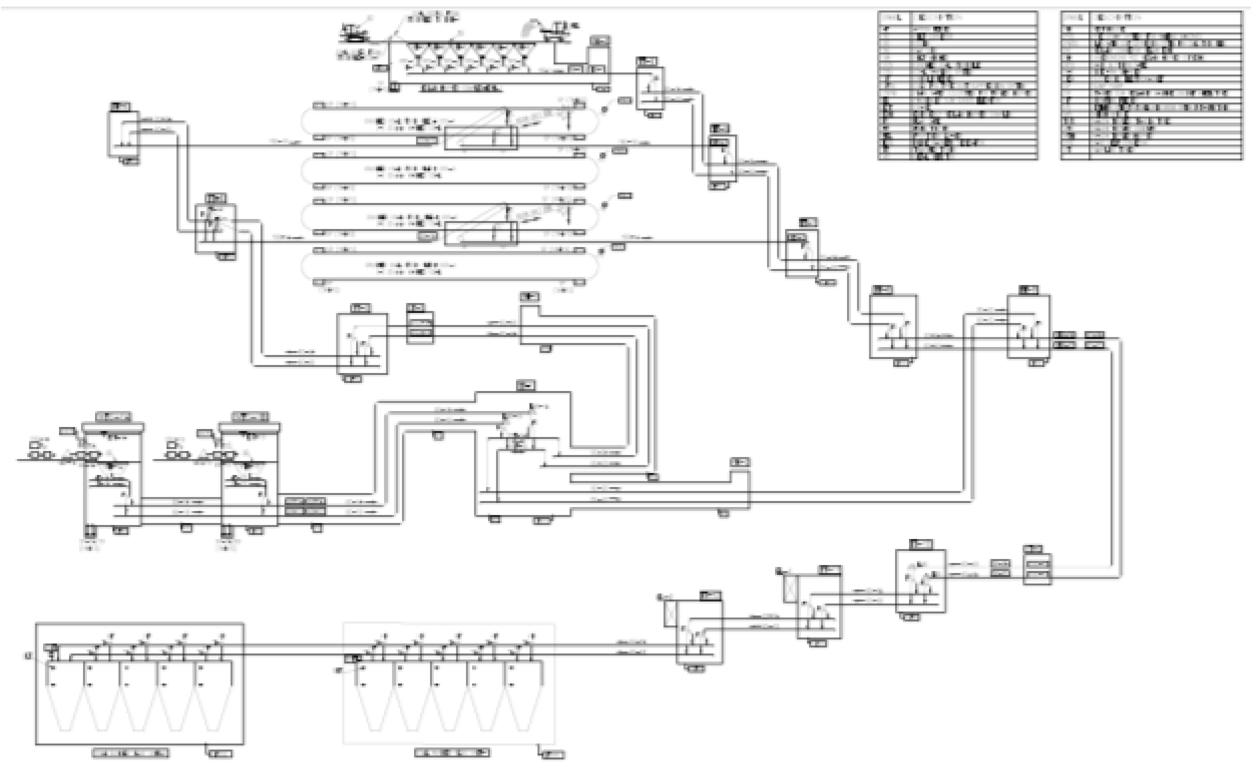


Figure 5.2-13 Flow Diagram of Coal Handling and Storage Facility

(2) The following tables describe the capacity requirements of CHP, belt selection criteria and stockpile capacity.

Table 5.2-10 CHP Capacity/No. of Tips Per Hour for Tandem Tippler

S.NO.	Item Description	Symbol	Unit	Formula/ref	Value
1	Installed capacity of proposed Power Plant	I_p	MW	---	2 × 660
2	Peak Hourly coal consumption (Worst Coal) for 1 × 660 MW unit	$C_{P'}$	tph	---	400
3	Peak Hourly coal consumption (Worst Coal) for 2 × 660 MW unit	C_P	tph	$C_P = 2 \times C_{P'}$	800
4	Peak coal consumption per day.	C_T	tpd	$C_T = 24 \times C_P$	19,200
5	Operating hr/day per CHP stream considered.	t	hr	---	12
6	Capacity of one CHP stream	C_o	tph	$C_o = C_T/t$	1,600
7	Capacity of one CHP stream with 10% margin	C_1	tph	$C_1 = 1.10 \times C_o$	1,760
8	No. of CHP stream	…..	…….	……………..	2 no (1W+IS)
9	Coal rake size i.e no. of wagon per rake	n_1	no.	One coal rake has 58 no. of wagons	58
10	Pay load per wagon	P_L	tonne	---	77
11	No. of tips per hour required per tippler	n_2	no.	$n_2 = C_1/P_L$	About 23
12	Type of Tippler proposed	----	----	2 wagons are tipped together in this tippler	Tandem
13	No. of tips per hour required per tandem tippler	n_3	no.	$n_3 = n_2 / 2$	12
14	Unloading rate per tandem tippler	q	tph	$q = P_L \times 2$ x n_3	1848
15	Hence capacity of CHP stream	Q	tph	Q = q	1848
16	Coal qty per rake [=rake load]	q_d	tonne	$q_d = n_1$ X P_L	4466
17	No. of coal rakes to be unloaded per day	n_4	no.	$n_4 = C_T \div q_d$	4.3
18	No. of coal rakes to be unloaded per day	n_4	no.	(Rounded Off)	5
19	No. of tippler(Tandem type) proposed	n_5	no.	---	2(1W+1S)

From above, we propose:

1. Tandem type tippler: 2 No. (1 Working + 1 Standby) × 12 tips/hr capacity each.
2. Capacity Of Each Belt Conveyor : 1848 tph, [for Coal @ 0.8t/m^3]
3. Operating hr per day for one CHP stream: - 19200÷1848 = 10.38 hr. Hence OK.

Table 5.2-11 Belt Speed & Width Selection for belt conveyors of CHP

S.No.	Item Description	Symbol	Unit	Formula/ref	1,800mm belt width × 35° tr
1	Capacity of CHP stream	Q	tph	Table-1	1,848
2	Area of load X 35° tr. belt 3-eq roll × 20° surcharge angle	A	m^2	IS: 11592,P-8	0.384
3	Material handled	----	----	----	(-)25mm Washed coal
4	Bulk density of material	ρ	t/m^3	----	0.8
5	Slope factor for 14° max. inclination of belt	K_1	----	----	0.91
6	Fill factor	K_2	----	----	0.95
7	Effective cross sectional area of load on belt	A_e	m^2	$Ae = AXK_1XK_2$	0.331968
8	Belt speed	V_s	m/s	Vs = Q/(3600Xρ X A_e)	1.93
9	Belt speed selected (minimum)	V	m/s	----	2
10	Fill factor (achieved)	K_{2n}	%	$K_{2n} = K_2 \times V_s/V$	0.92
11	Check capacity of conv. @ selected belt speed	Q_C	tph	Q_C = 3,600Xρ X A_e X V	1,912 > 1,848 Hence O.K

From Above,

Belting proposed 1800mm wide x 35° tr belt x 3-eq roll x approx. 2.0 m/s belt speed

Table 5.2-12 Stockpile Details

S.No.	Description	Value
1	Material Handled	Coal,(-)25 mm
2	Daily fuel consumption, tonne (See Table-1)……(x)	19200
3	Type of cross section of stockpile	Trapezoidal
4	Height of each stockpile, m……….(h)	10
5	Width of stockpile at base, m……(b1)	45
6	Width of stockpile at top, m…..…(b2)	18.46
7	Cross sectional area, sqm, $y=0.5 \times (b1+b2) \times h$	317.3
8	No. of stockpiles provided for uncrushed coal	Four(4)
9	Capacity of Stockpile for coal in tonne per running meter(coal @ 0.8t/cum), z=0.8 x y	253.84
10	Length of each stockpile, m (See Layout plan)…..…L, (m)	500
11	Hence capacity of one stockpile, $C_o = L \times z$	126,920
12	Hence capacity of Four (4) stockpile, $C_1 = 4 \times C_o$	507,680
13	No. of days coal storage capacity available in above stockpiles [@ 100% PLF], d…………….$d=C_1 \div x$	26
14	No. of days coal storage capacity available in above stockpiles [@ 90% PLF], d_1…………….$[d_1=d \div 0.9]$	29

5.2.10 Ash Handling Plant:

(1) Ash Handling System

The ash handling system will be designed to meet the following requirements:

Table 5.2-13 AHP Design Parameters

S. No.	Description	1 × 660 MW	2 × 660 MW
a)	Coal consumption at full load per hour	332.92TPH	665.84TPH
b)	Ash content	37%	37%
c)	Ash generated	123.18 TPH	246.36 TPH
d)	Bottom ash generated 20%	24.64 TPH	49.27 TPH
e)	Fly ash generated 90%	110.86 TPH	221.73 TPH

(2) Bottom Ash Handling System

Ash formed due to combustion of pulverized coal in the steam generator will be collected on dry bottom ash conveyor at the bottom of furnace and conveyed to Bottom Ash Silo for further disposal.

Dry Bottom ash conveying system consists of a refractory lined Dry Bottom Ash Hopper connected to the Boiler furnace through a mechanical seal capable of absorbing Boiler thermal expansions. The Bottom of hopper will be equipped with bottom doors to isolate conveyor system in case of emergency / maintenance purpose. The Bottom Ash hopper will be provided with temporary storage volume.

During normal operation, the Bottom ash collected on the dry bottom ash conveyor will be crushed to size by means of crushers installed at end of conveyor before discharge on to secondary conveyor which ultimately discharges bottom ash into Bottom ash Silo.

One (1) – 100 Ton capacity Ash Silo in steel construction shall be provided. Bottom ash silo shall be of conical bottom with SS lines on sloped portion.BA Silo shall be provided with two outlets for disposal of Bottom ash.

Flow Diagram of Bottom Ash Handling System is indicated in Figure 5.2-14.

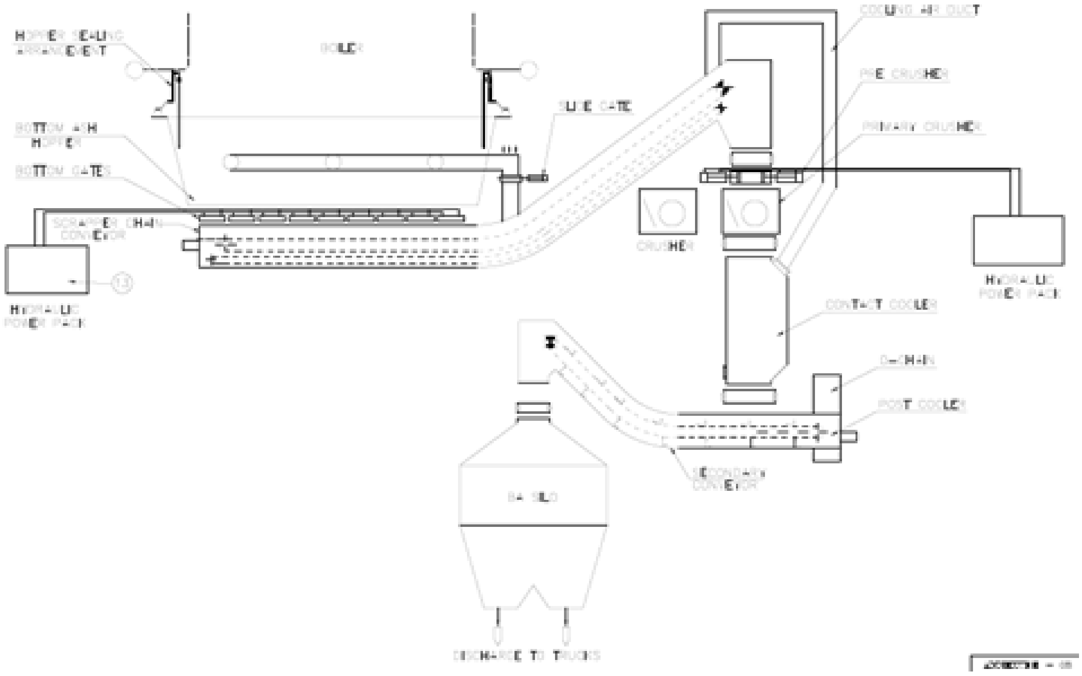


Figure 5.2-14   Flow Diagram of Bottom Ash Handling System

(3)   Fly Ash Handling System

As per flow diagram of fly ash handling system, Fly ash collected in various ESP, shall be extracted and conveyed in dry form up to fly ash silos. Fly ash from the ESP field hoppers is conveyed through independent and parallel conveying lines to six Combination Filter Separator cum Buffer Hopper units.

Fly ash will be extracted and conveyed to buffer hoppers automatically and sequentially by means of vacuum generated by mechanical exhauster and will be transported to fly ash silos by means of pressure conveying system.

Adequately rated oil free rotary screw type Conveying Air Compressors will be provided to supply compressed air required for conveying fly ash from buffer hoppers to fly ash silos. One (1) buffer hopper will be provided for each vacuum stream. Adequately sized bag filters will be mounted on buffer hopper. Three (3) streams are proposed for conveying the fly ash from buffer hoppers to Fly ash silos.

Below each buffer hopper, two ash vessels /air lock vessels will be provided to convey ash to fly ash silos.

Two (2) fly ash storage silos in RCC construction will be provided for each unit, each having an effective storage capacity of storing 24 hours. Fly ash silo will be provided with four outlets; one for unloading ash in dry form into closed trucks through telescopic chute; one for unloading ash in conditioned form into open trucks through ash conditioner, one for disposing Fly ash in HCSD form through HCSD pumps and one outlet blind flanged for future use. Fly ash storage silo will be provided with adequately rated vent filter on silo roof.

Three (3) adequately rated low speed, oil free, lobe type fluidizing air blowers with heaters will be provided for fluidizing ESP & APH Hoppers, two working and one standby.

Three (3) adequately rated low speed, oil free, lobe type fluidizing air blowers with heaters will be provided for fly ash silo; two working and one standby.

Two (2) adequately rated oil free screw compressors with HOC type air driers and air receivers will be provided for supplying instrument air for various valves and cleaning of pulse jet type bag filters.

Flow Diagram of Fly Ash Handling System (ESP Area) is indicated in Figure 5.2-15 below.

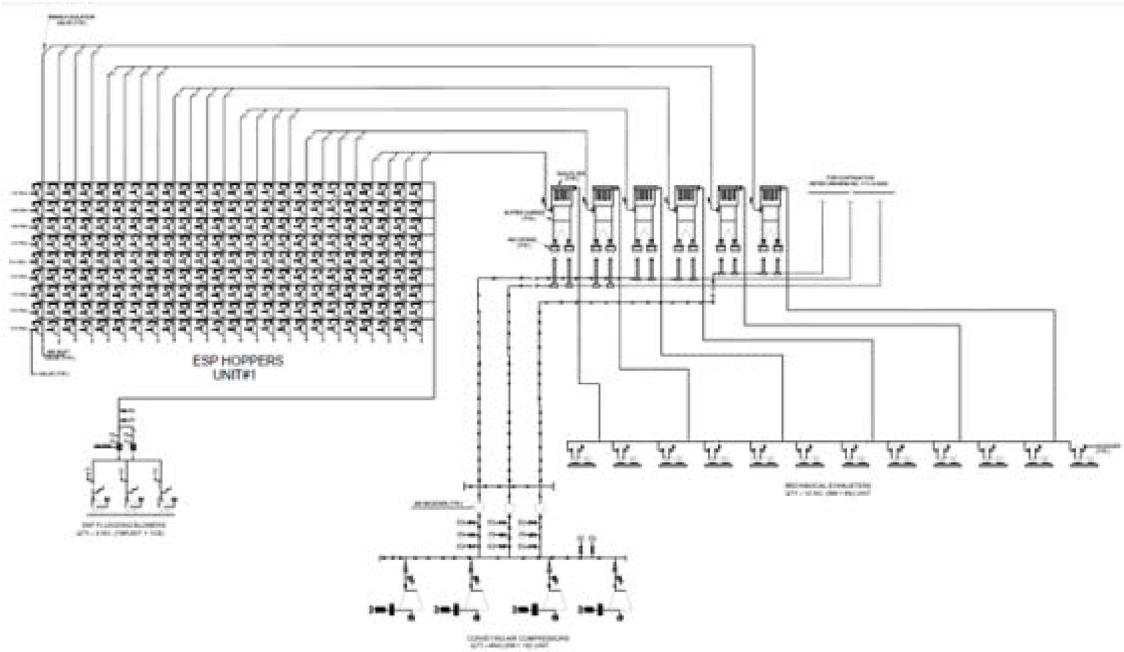


Figure 5.2-15 Flow Diagram of Fly Ash Handling System (ESP Area)

(4) Fly Ash Slurry Disposal System

The ash from fly ash silos will be fed by rotary feeders and ash conditioners into the slurry mixing tank, the level of which will be controlled. The conditioned dry fly ash will be wetted out by water to be added in the mixing tank and the entire ash will blended to a uniform consistency by mixer.

One (1) mixing tank and one (1) ash slurry pump (HCSD type) will be provided for each fly ash silo. Each HCSD pump discharge piping will be provided up to the disposal area with all necessary isolation valves, line flushing valves etc. The ash slurry pump will be suitably designed for high concentration disposal (HCSD) system and necessary pulsation dampeners/accumulator immediately after slurry pump discharge and/or on discharge lines.

The mixing tank will be sufficiently large to provide a reasonable residence time so that short term fluctuations in concentration can largely be blended out.

The ash mixing and pumping process will operate in cyclic mode and automatically dispose of ash so as to accommodate changes in ash production caused by fluctuating boiler loads or other variables.

Ash disposal pipelines will be installed above ground with flange joints wherever necessary and it will suit the maximum pressure encountered in the pipeline or otherwise pipelines will be welded. The ash slurry disposal will be designed for 65-70% concentration (solids by weight).

The disposal area will be filled in such a way that the deposits can reach the required height within the area and no ash retaining structures are to be constructed.

Flow Diagram of Fly Ash Handling System (Silo Area) is indicated in Figure 5.2-16 below.

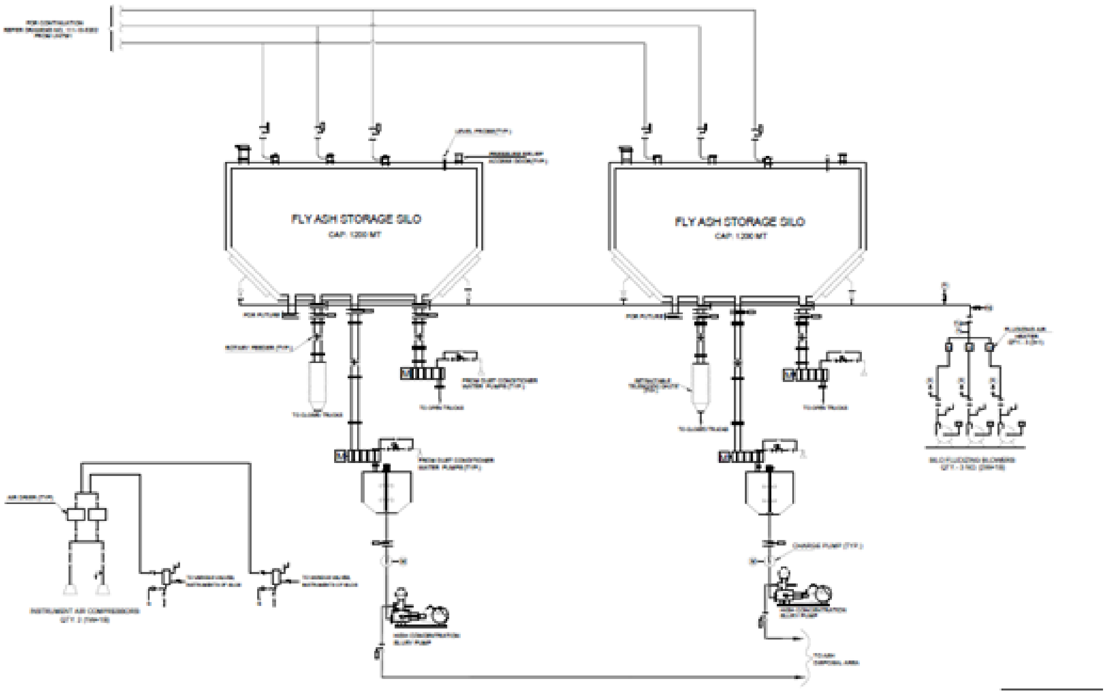


Figure 5.2-16 Flow Diagram of Fly Ash Handling System (Silo Area)

(5) System Capacities

1) Bottom Ash Handling System

The rated capacity of the Bottom Ash handling system will be 50TPH to remove the Bottom ash on continuous basis.

2) Fly Ash Handling System

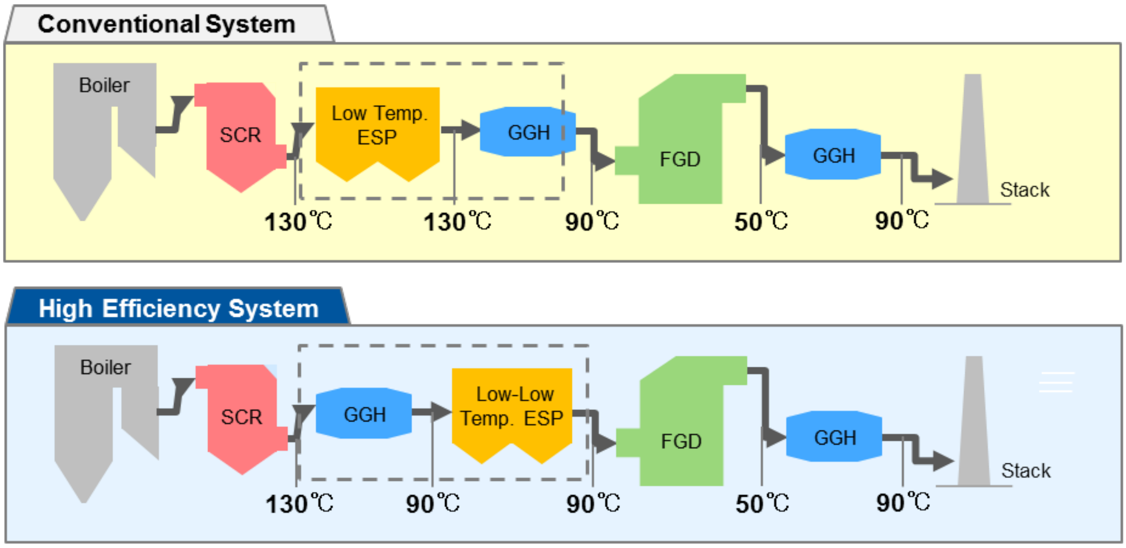
Ash collected in ESP and stack hoppers in a shift of eight (8) hours will be evacuated within 6.0 hours. The capacity of the individual lines and grouping of various ash hoppers will be based on the standard vacuum pump capacity.

5.2.11 Air Quality Control Systems (AQCS)

(1) AQCS

A high efficiency AQCS is adopted for this project as shown below, which is a combined system of the latest environmental pollution control facilities applied in Japan normally.

Whereas the flue gas temperature at electrostatic precipitator (ESP) inlet is around 130°C in the conventional AQCS (Low Temp. ESP), in the high efficiency AQCS it is around 90°C by locating gas-gas heater (GGH) heat recovery unit upstream of ESP (Low-Low Temp. ESP). Because of its lower flue gas temp., the removal of dust and SO_3 is enhanced and also the size of ESP can be reduced. The following shows a comparison of the conventional AQCS and high efficiency AQCS.



	High Efficiency System	Conventional System
Electrostatic Precipitator (ESP)	- Easier to remove dust due to lower electric resistivity - Higher performance / downsized	- Higher electric resistivity (more difficult to remove dust) - Larger sizing - 100 – 200 mg/Nm^3 of outlet dust conc. (limitation by SO_3)
Flue Gas Desulphurisation (FGD)	- No limitation of inlet dust load - Up to 10 mg/Nm^3 of outlet dust concentration	- 100 – 200 mg/Nm^3 of inlet dust load
Gas-Gas Heater (GGH)	- No concern about SO_3 corrosion - Reduction of corrosion potential for downstream equipment	- Concern about sedimentation / clogging of wet dust

1) Countermeasures against NO_x (nitrogen oxide)

Low NOx burners and two-staged combustion in the boiler furnace, and Selective Catalytic Reduction (SCR) system for flue gas denitrification are adopted to meet the required NO_x emission value of 100 mg/Nm^3.

SCR reactor with catalyst and ammonia injection grid are installed between economizer and air-preheater. Through the catalyst, the ammonia and NOx in the flue gas are converted to harmless nitrogen and water as shown below.

$$4NH_3 + 4NO + O_2 \rightarrow 4N_2 + 6H_2O$$
$$8NH_3 + 6NO_2 \rightarrow 7N_2 + 12H_2O$$

Table 5.2-14 shows the specification of SCR system and a typical outline of SCR reactor is shown in Figure 5.2-17.

Table 5.2-14 Basic Specification of Scr System

Item	Unit	Specs
Type of flue gas denitrification	-	SCR
SCR inlet flue gas flow rate	Nm^3/h	2,091,600
SCR inlet NOx concentration	ppmvd @6%O_2	327
SCR outlet NOx concentration	ppmvd @6%O_2	44
NO_x removal rate	%	86.5
Reactor dimensions	m	16W × 10L × 20H
Amount of reactor	-	2
Reductant (reducing agent)	-	Gaseous ammonia (NH_3)
Type of SCR catalyst	-	Plate catalyst
Ammonia (NH_3) consumption	kg/h	450

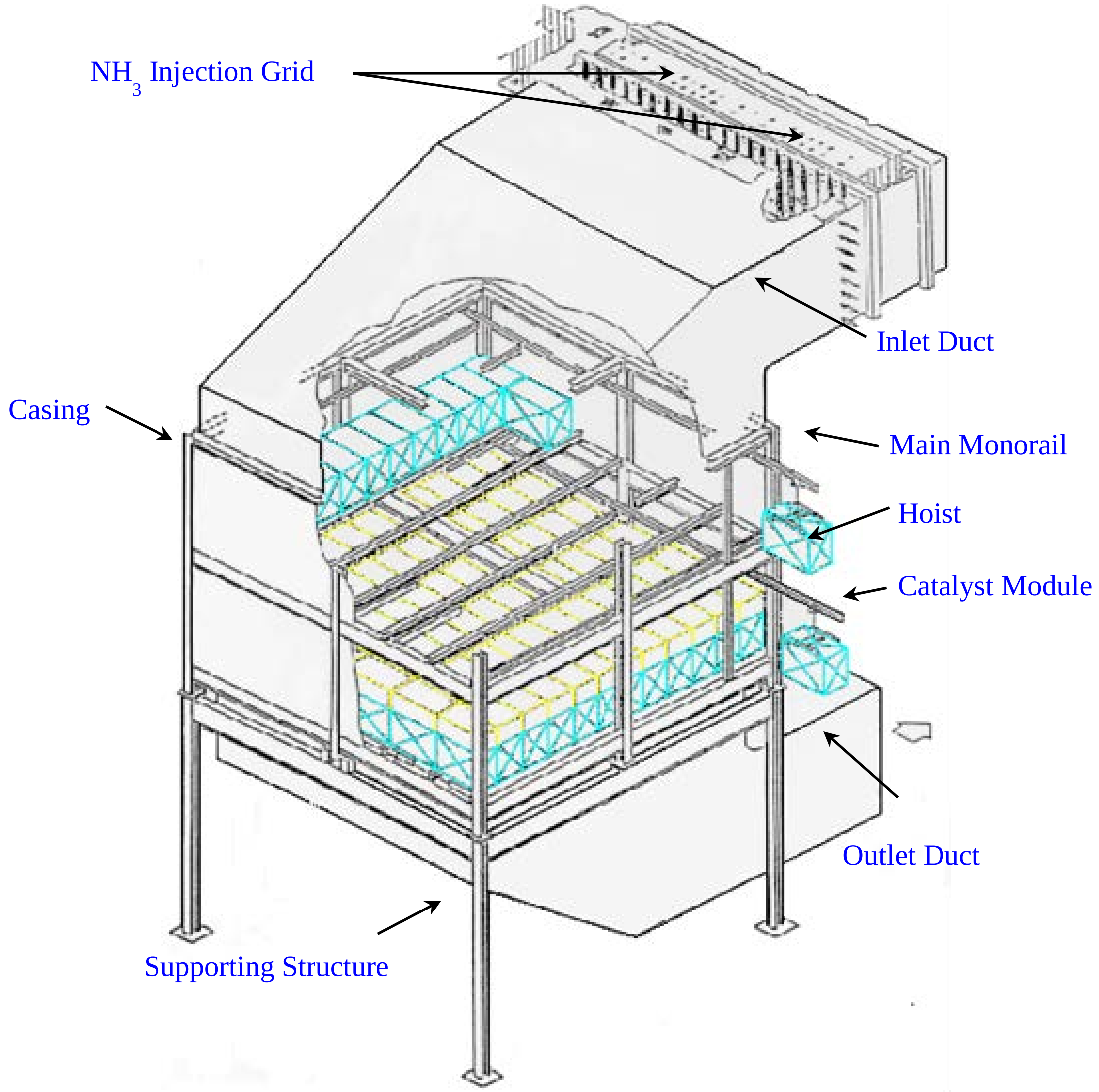


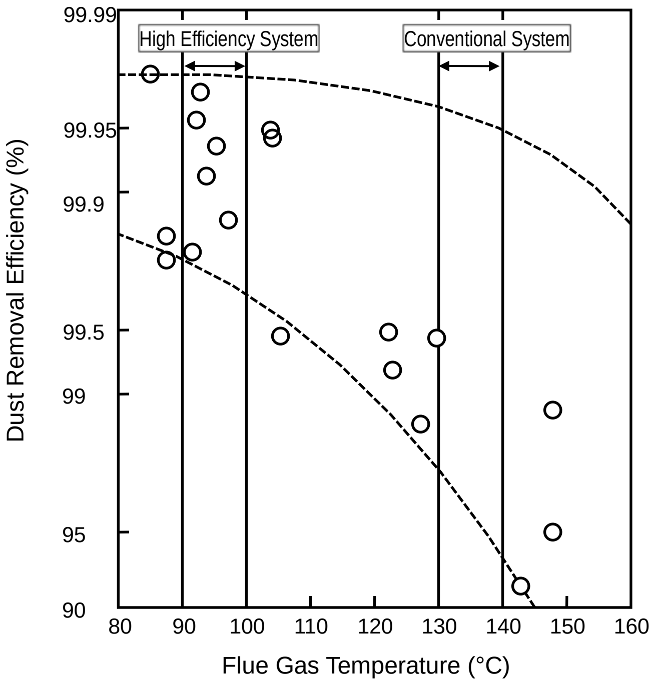
Figure 5.2-17 Outline Illustration of Scr Reactor

2) Countermeasures against dust and/or particle matters (PM)

An ESP is installed downstream of a GGH heat recovery (i.e. gas cooler) unit and dust/PM in the flue gas is removed there.

Low-Low Temp. ESP

By arranging the GGH heat recovery unit upstream of ESP, ESP inlet flue gas temp. becomes approximately 90°C (Low-Low Temp. ESP) as opposed to 130 – 140°C in the conventional system. This enables more highly-efficient removal of dust/PM and SO_3, and smaller ESP sizing because of reducing the actual flue gas volume by lower flue gas temp. The following shows a relationship between flue gas temp. and dust removal efficiency at ESP.



Relationship between flue gas temp. and dust removal efficiency at ESP

The flue gas passes through several sections in the ESP with evenly distributed and parallel. While passed through these sections, dust/PM is captured and collected with the electrostatic effect by a high-voltage electrode system in the ESP.

The main component of ESP is as follows. Table 5.2-15 presents the specification of ESP and general structural drawings of ESP are shown in Figure 5.2-18 and Figure 5.2-19.

- Ash hoppers
  Inverse pyramid hoppers are installed at the bottom of ESP casing. The hopper inclination angle is designed at approximately 60 deg.

- Collecting electrodes
  A dust collecting electrode is a group of several roll plates. These plates are loaded inside of ESP as a module and hung from the steel structure of ESP.
- Discharging electrodes
  A rigid discharging electrode is consist of "a pipe and spikes (pins)".
- High-voltage (HV) equipment (HV cubicles and HV rectifiers)
  Every area of ESP has a set of transformer/rectifier (T/R set). The T/R set is equipped with a transformer/rectifier unit and control cubicle.

Table 5.2-15 Basic Specification of Esp

Item	Unit	Specs
Stream nos. of ESP		2 streams / boiler
ESP inlet flue gas flow rate	Nm^3/h	2,164,800 / boiler
ESP inlet dust concentration (dry, actual O_2)	mg/Nm^3	109,200
ESP outlet dust concentration (dry, 6%O_2)	mg/Nm^3	100
Dust removal rate at ESP	%	99.9

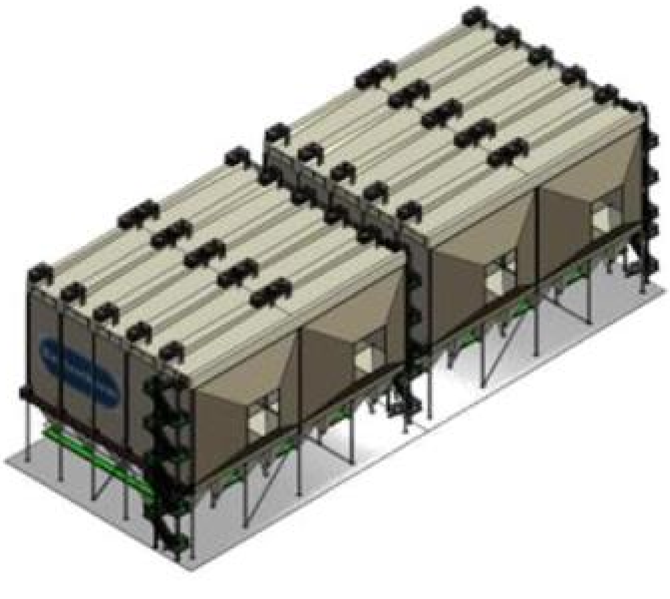


Figure 5.2-18 3D Model of ESP

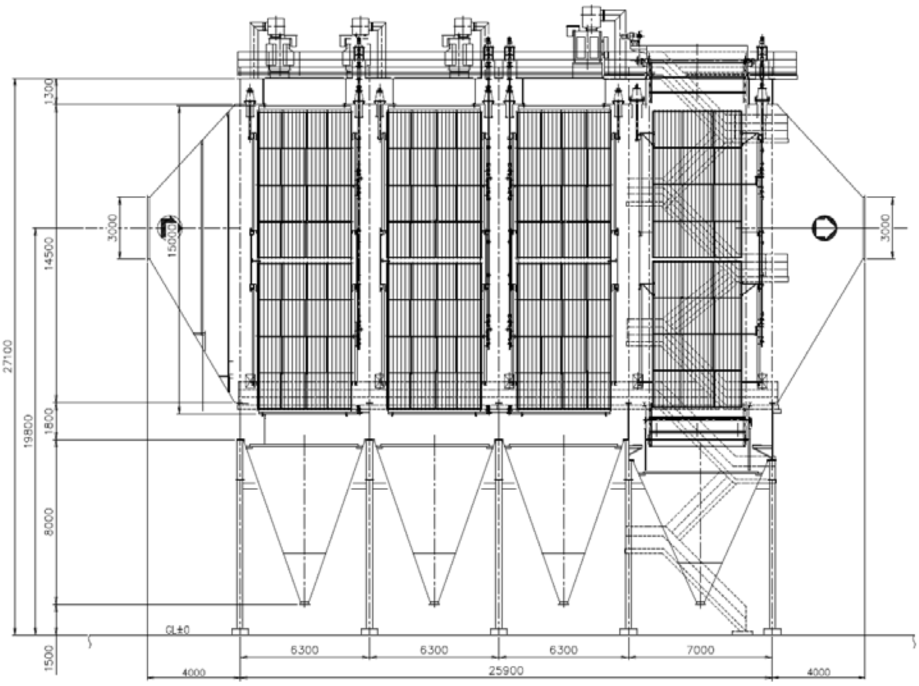


Figure 5.2-19 Side view of ESP

3) Countermeasures against SO_x (sulphur oxide)

(a) Selection of flue gas desulphurisation (FGD) process

The planned emission values of SOx and dust are 100 mg/Nm^3 and 30 mg/Nm^3 respectively, and an FGD system is installed to fulfill them. For SOx and dust removal, a standard wet limestone-gypsum process FGD is adopted.

The high efficiency AQCS consists of the Low-Low Temp. ESP, GGH and this FGD system.

<u>Non-Leakage GGH (heat transfer medium forced-circulation type)</u>

This GGH system enables its reliable heat recovery/reheat under a high dust load condition. A typical configuration diagram of non-leakage GGH is shown below.

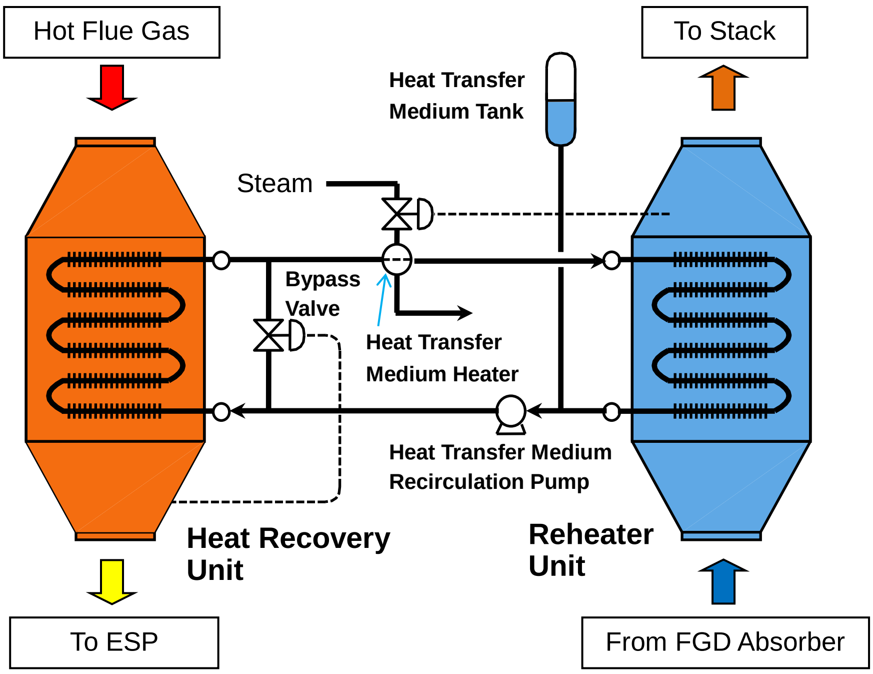


Figure 5.2-20 Configuration diagram of non-leakage GGH

Though there are common problems of sulphuric acid dew point corrosion and clogging by the dust particles in the heat recovery from the flue gas, this GGH is enough reliable owing to the features below:

1. Heat transfer medium temperature control system

   The heat transfer medium is heated with a heat transfer medium heater to avoid its temperature falling below a set point. By this heat medium temp. control system, corrosion of heat transfer tubes is mitigated and furthermore moistening/fixation of the dust on the tubes is prevented during boiler load changes and/or short-term shutdown, and therefore the stable and sustained operation can be achieved. Besides, the steady operation can be carried out in a short time from the start-up by preheating the heat transfer medium in advance.

2. Outlet flue gas temperature control system

   In order to avoid a significant temperature fall of the flue gas at the heat recovery unit outlet due to boiler load changes, there is a bypass system of the heat transfer medium, and it contributes to mitigate corrosion of heat transfer tubes.

3. Squarely arranged heat transfer tubes

Erosion/abrasion of heat transfer tubes by the ash attack is unavoidable under a high dust load condition, however, the squarely arrangement of heat transfer tubes makes them more abrasion-resistant compared with a staggered arrangement.

Absorber in FGD System

There are two FGD absorber types; a double contact flow scrubber (DCFS) which is especially good for high SO_2 load/removal, and spray tower scrubber which has a good balance between SO_2 removal and economy. The appropriate absorber type is selected based on the inlet SO_2 load and required SO_2 removal performance, and for this project the spray tower scrubber is adopted. A general outline of spray tower absorber is shown below.

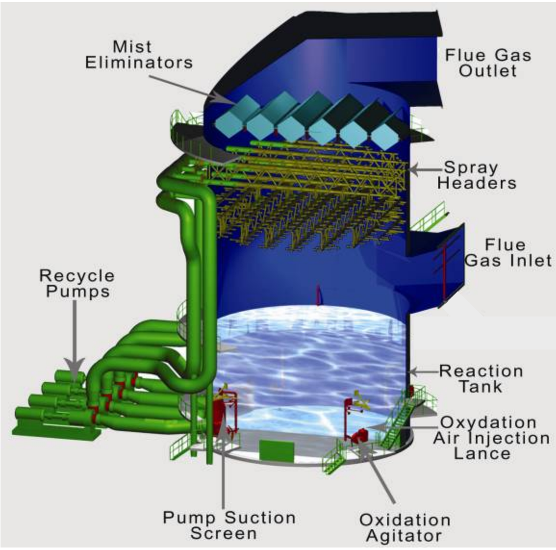


Figure 5.2-21 General outline of spray tower absorber

(b) System configuration of FGD system.

The wet limestone-gypsum process is adopted as FGD process, in which limestone is used for an absorbent and gypsum is recovered as a by-product. Figure 5.2-22 shows a process flow diagram of AQCS with FGD system and Table 5.2-16 shows the design conditions of FGD system.

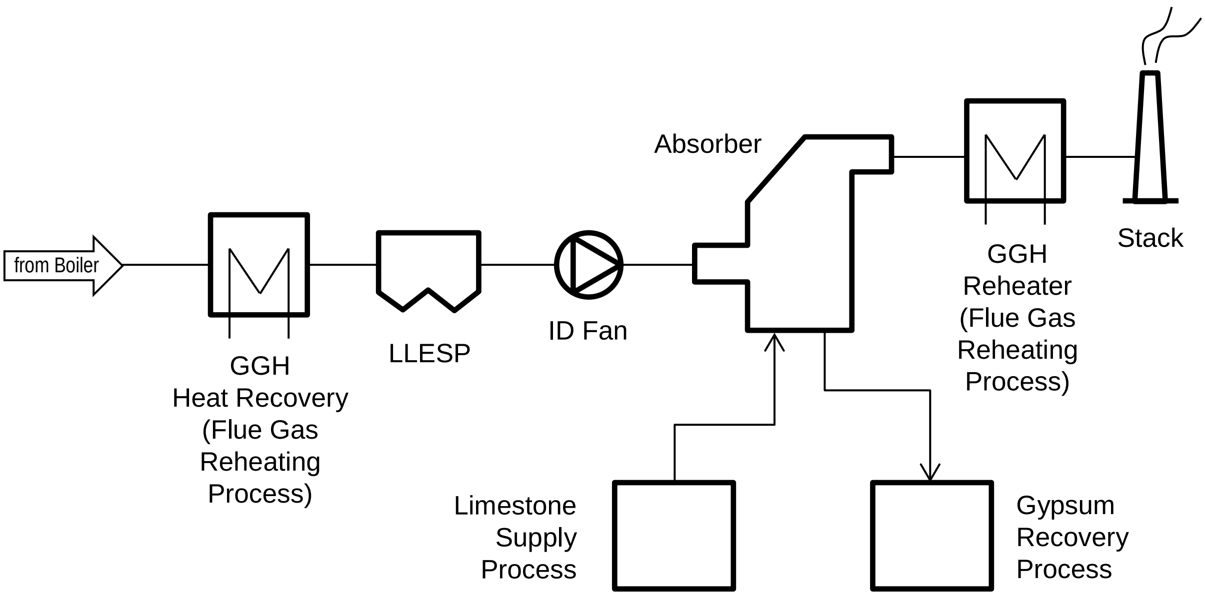


Figure 5.2-22 Process Flow Diagram of AQCS with FGD System

Table 5.2-16 FGD design Conditions

Item	Unit	Specs
Design coal	-	Best Coal (max. SOx coal)
FGD inlet flue gas flow rate	Nm^3/h	2,164,800
Absorber type	-	Open spray tower
FGD inlet SOx concentraion (dry, 6%O_2)	mg/Nm^3	1,746
	ppmvd	611
FGD outlet SOx concentraion (dry, 6%O_2)	mg/Nm^3	100
	ppmvd	35
SOx removal rate in FGD	%	94.3
Limestone Consumption (96% purity)	kg/h	5,850

a) Absorption and oxidation process

Absorber system is equipped with an absorber, spray piping/nozzles, absorber recirculation pumps, oxidation air blowers, etc. Flue gas is entered from absorber inlet duct and then contacted with slurry countercurrently sprayed from spray nozzles, where SO_2 gas in the flue gas is absorbed/removed. At the absorber tank part, there are oxidation agitators to prevent the sedimentation of slurry and to oxidise calcium sulphite ($CaSO_3$) formed from absorbed SO_2. At absorber outlet part, entrained slurry and mist in the flue gas are removed with mist eliminators, which are washed with water regularly by washing system to avoid scaling on them. Table 5.2-17 shows the specifications of equipment in this process.

Table 5.2-17 Equipment Specifications in Absorption/Oxidation Process

Item	Unit	Specs
Absorption/oxidation process		
Absorber dimensions	m	ϕ16.0 m (dia.) × 29.1 mH (dia. of tank: ϕ 17.2 m)
Absorber tank volume	m^3	1,510
Amount of spray stages	stages	3 + 1 standby
Absorber shell material	-	Carbon steel with flake resin lining (FRL)
Liquid-gas ratio (L/G)	litters/Nm^3	11.1
Absorber recirculation pump		
Amount	units	3 + 1 standby
Capacity	m^3/min.	126
Head	mLq	18.0 / 19.5 / 21.0 / 22.5
Motor rated capacity	kW	550 / 600 / 640 / 690
Mist eliminator		
Type	-	Chevron type
Amount	units	1 (2 stages)
Material	-	FRP
Oxidation air blower		
Amount	units	1 + 1 standby
Capacity	Nm^3/h, dry	5,400
Head	kPa	81
Motor rated capacity	kW	200
Absorber oxidation agitator		
Type	-	Side entry propeller type
Amount	units	4
Motor rated capacity	kW	55
Absorber bleed pump		
Amount	units	1 + 1 standby
Capacity	m^3/min.	1.33
Head	mLq	30
Motor rated capacity	kW	18.5
Others		
Absorber drainage pit with agitator and pumps		
Absorber slurry blow down tank		

b) Flue gas reheating process

Flue gas reheating process consists of a GGH heat recovery unit to cool down the untreated hot flue gas and GGH reheater unit to heat up the treated (clean) cold flue gas. Water is used as the heat transfer medium and circulated between these GGH units to exchange heat with the flue gas. By this means, the heat of hot flue gas at upstream of FGD system is used as an effective way to reheat the cold flue gas at absorber outlet, and it contributes to improve the diffusion of flue gas from the stack.

In each GGH unit, finned tubes are adopted to heat transfer tube bundles in order to enhance the heat exchange efficiency and steam soot blowers are installed for the removal of dust on these tubes. The specifications of equipment in the flue gas reheating process are shown in Table 5.2-18.

Table 5.2-18 Equipment Specifications in Flue Gas Reheating Process

Item	Unit	Specs
Flue gas reheating process		
GGH heat recovery unit		
Type	-	Forced-circulation heat medium, multitubular type
Heat exchange duty	GJ/h	108.8
Material	-	Carbon steel
GGH reheater unit		
Type	-	Forced-circulation heat medium, multitubular type
Heat exchange duty	GJ/h	127.6
Material	-	Sulphuric acid resistant steel / Carbon steel
Heat transfer medium recirculation pump		
Amount	units	1 + 1 standby
Capacity	m^3/min.	12.1
Head	mLq	80
Motor rated capacity	kW	220
Soot blower for heat recovery unit		
Type	-	Steam blowing, retractable
Amount	units	16
Blowing pressure	MPa	0.98
Blowing quantity	t/h/unit	2.8

Item	Unit	Specs
Motor rated capacity	kW	1.5
Soot blower for reheater unit		
Type	-	Steam blowing, retractable
Amount	units	24
Blowing pressure	MPa	0.98
Blowing quantity	t/h/unit	2.8
Motor rated capacity	kW	1.5
Others		
Heat transfer medium tank		
Heat transfer medium heater		
Drain tank for heat transfer medium heater		
Drain pump for heat transfer medium heater		
Sealing air fan for heat recovery		
Sealing air fan for reheater		

c) Gypsum recovery process

Gypsum recovery process is composed of vacuum belt filters, vacuum pumps, hydrocyclones, filtrate water tank, etc. In this process, the gypsum slurry extracted from the absorber tank is dewatered and the by-product gypsum is transferred to and stored in a gypsum storage shed. A part of filtrate water from belt filters is constantly purged to a wastewater treatment system to avoid accumulation of inert matters/impurities in the FGD system. Table 5.2-19 shows the specifications of equipment in this process.

Table 5.2-19 Equipment Specifications in Gypsum Recovery Process

Item	Unit	Specs
Gypsum recovery process		
Belt filter supply tank		
Type	-	Vertical cylindrical
Dimensions	m	ϕ 5.9 m (dia.) × 5.9 mH
Material	-	Carbon steel
Agitator for belt filter supply tank		
Type	-	Top entry propeller type
Motor rated capacity	kW	7.5

Item	Unit	Specs
Belt filter supply pump		
Amount	units	1 + 1 standby
Capacity	m^3/min.	2.7
Head	mLq	45
Motor rated capacity	kW	45
Vacuum belt filter		
Type	-	Horizontal vacuum belt filter
Amount	units	1 + 1 standby
Capacity	t/h	21.1 (dried gypsum base)
Moisture content	wt.%	< 10
Motor rated capacity	kW	5.5
Accessories		
Cloth wash tank		
Cloth wash pump		
Gypsum cake wash pump		
Vacuum pump		
Vacuum receiver & pump		
Filtrate water pump		
Amount	units	1 + 1 standby
Capacity	m^3/min.	1.83
Head	mLq	55
Motor rated capacity	kW	37
Filtrate water tank		
Type	-	Vertical cylindrical
Dimensions	m	ϕ 6.6 m (dia.) × 6.6 mH
Material	-	Carbon steel with FRL
Agitator for filtrate water tank		
Type	-	Top entry propeller type
Motor rated capacity	kW	7.5
Purged water pump		
Amount	units	1 + 1 standby
Capacity	m^3/min.	0.33
Head	mLq	25
Motor rated capacity	kW	3.7
Purged water tank		
Type	-	Vertical cylindrical

Item	Unit	Specs
Dimensions	m	Φ3.6 m (dia.) x 3.6 mH
Material	-	Carbon steel with FRL
Agitator for purged water tank		
Type	-	Top entry propeller type
Motor rated capacity	kW	3.7
Others		
Gypsum dewatering area drainage pit with agitator and pumps		

d) Limestone supply process

In limestone supply process, wet ball mill system is adopted to grind lump limestones and prepare limestone slurry. The limestone slurry is stored in a limestone slurry tank and a necessary amount is supplied to the absorber by a limestone slurry pump. Table 5.2-20 shows the specifications of equipment in the limestone supply process.

Table 5.2-20 Equipment Specifications in Limestone Supply Process

Item	Unit	Specs
Limestone supply process		
Limestone weighing conveyor		
Type	-	Weighing conveyor
Amount	units	1 + 1 standby
Capacity	t/h	24
Motor rated capacity	kW	5.5
Wet ball mill		
Amount	units	1 + 1 standby
Capacity	t/h	24
Motor rated capacity	kW	610
Accessories		
Inching device		
Lubrication pump		
Lube oil cooling fan		
Classifier (hydrocyclones)		
Mill slurry tank		
Mill slurry pump		
Agitator for mill slurry tank		

Item	Unit	Specs
Limestone slurry pump		
Amount	units	1 + 1 standby
Capacity	m^3/min.	0.6
Head	mLq	35
Motor rated capacity	kW	11
Limestone slurry tank		
Type	-	Vertical cylindrical
Dimensions	m	ϕ 9.6 m (dia.) × 9.6 mH
Material	-	Carbon steel with FRL
Agitator for limestone slurry tank		
Type	-	Top entry propeller type
Motor rated capacity	kW	30
Others		
Limestone supply area drainage pit with agitator and pumps		

e) Other utility system

There is other equipment to supply utilities in the FGD system such as wash water, makeup water, etc. The specifications in the other utility system are shown in Table 5.2-21.

Table 5.2-21 Equipment Specifications in Other Utility System

Item	Unit	Specs
Other utility system		
Mist eliminator wash tank		
Type	-	Vertical cylindrical
Dimensions	m	ϕ 5.7 m (dia.) × 5.7 mH
Material	-	Carbon steel
FGD makeup water pump		
Type	-	1 + 1 standby
Amount	units	1.53
Capacity	t/h	40
Motor rated capacity	kW	22

5.3 Conceptual Design of Civil & Architectural Works

5.3.1 Site Preparation

(1) General

The New Plant shall be constructed in the ash disposal area to utilize the site efficiently. As a practical construction, it is necessary to survey to obtain the ground property before beginning the construction. In general, Ash disposal area is soft ground and has the folloing problem.

- Consolidation Settlement
- Liquefanction
- Lateral Displacement
- Circular Slide

The countermeasure to the above shall be the following ground Improvement.

1) Preloading method
2) Sand Compaction Pile method
3) Deep Mixing method

To determine the countermeasure, it is necessary to concider facility specification, construction period and cost such as detailed ground property and value of allowable stress and displacement. In this study, Stone compaction pile metod that is past result in India shall be adopted. In detailed design, diameter, interval and arrangement of Pile shall be dicided to concider the loading and foundation of the upper facilities.

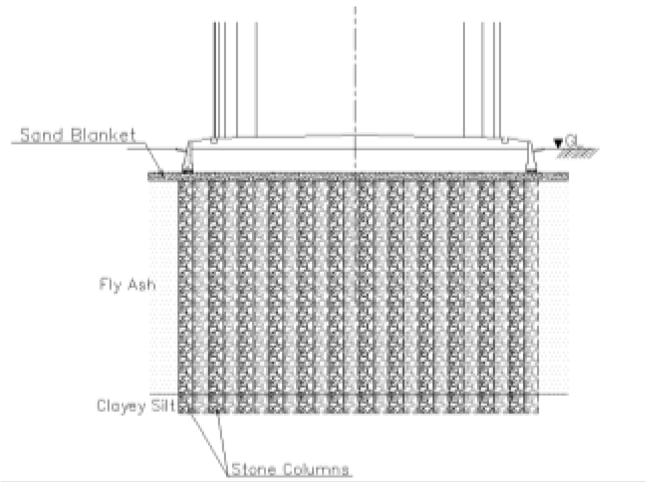


Figure 5.3-1 Example of Stone Compaction Pile method

(2) Construction Flowchart

1) Excavation and Filling

Land will be cut by back hoes, and loaded to dump truck, and transported to the filled area. Bulldozers will fill and level the site.

2) Sand mat (Leveling the borrow and fine material)

The surface soil (50cm thick) will be filled to improve trafficability for construction machine of Stone Compaction Pile method. The sand will be transported from near site, and leveled and compactied by bulldozers.

3) Ground Improvement

The Stone Compaciton Pile will be constructed in Ash disposal layer by the machine of Stone Compaciton Pile method remodeled crawler crane.

5.3.2 Intake structures

(1) General

Raw water will be planed to take from the near river or canal. The determination of the location of intake structures should be considered after the new plant site has been determined. The main structures shall have intake, inlet channel, pump house and water reserver.

Method of intake should be adopted as appropriate according to the stream regime. The major methods and characteristics of Intake are following.

- Intake weir

  Water level is stead higly to set weir across the river, and water will been taken from inake.

- Intake gate

  Gate is set at the bank of a river and water will be taken from it. To take water stably, weir can be constructed at the downstream.

- Intake tower

  In case the change of water level is big, tower type intake will be constructed and water will be taken from the side wall of the tower.

Detaile type and stuctures of the Inlet channel and Pump house shall be determined according to the distance of intake and plant site (water reservor) and so on.

(2) Design condition

(a) River flow condition

Each of flood water level, drought water level and ordinary water level of the river needs to be confirmed upon the river survey, where water flow, water lever water quality and sediment deposition are to be identified.

With regard to the use of river water, relevant laws and regulations such as water right and permission for occupancy shall be confirmed prior to the construction of intake structures.

(b) Flow volume

The maximum cooling water consumption for 2 × 660 MW plant shall be 3,300 m^3/h (0.916 m^3/s).

5.3.3 Ash Disposal area

(1) Selection of a site

The ash produced during combustion of coal should be recycled and reused as cement material, other construction materials etc. as much as possible. The balance of the ash that cannot be recycled or reused shall be disposed in ash pond.

The following conditions would be advisable for ash disposal area.

- Near the power plant to save the distance for ash transpotation,
- The ground should be impermeable enough,
- The ground should be sound enough and may not cause settling / land slinding,
- Neither source of a stream not water intake should be near the ash disposal area, and
- Not too much windy area to avoid flying ash.

In this study, the ash disposal area should be located above a part of the past ash disposal area. It would be better to carry out futher site survy and geological investigation at the proposed site in order to fix the dinal detailed structure for the ash disposal area.

(2) Capacity of Ash disposal area

The ash disposal area shall be located near the power plant. As well as carry out the soil covering providing a windbreak to prevent the ash scattering from the ash disposal area, installing a sprinkler system for shatterproof. The capacity of the ash disposal area is as follows;

Design Condition

- Fuel coal consumption of Maximum Ash Content Coal (1unit) : 329 t/h
- Plant efficiency with Average Ash Content Coal : 37%
- Bottom Ash : Fly Ash ratio : 20% : 80%
- Plant factor : 80%
- Specific gravity of disposal ash : 0.9 t/m^3
- Ash utilization ratio : 50 %
- Life time of ash disposal area : 10years
- Hight of Ash dyke (containing soil-cover) : 10 m

Area of the ash disposal area estimated as follows;

- Ash generation : 1,706,000 t/year
- Amount of disposal ash : 1,023,600 t/year
- Total amount of disposal ash for 10 years : 10,236,000 t
- Area of the ash disposal area : About 120 ha

(3) Water Sealing Structures

It shall be assumed that the ash disposal area located ash pond in doesn’t water sealing structures. However, it is set under the Indian laws that the ash disposal area has the water sealing structures and effluent standard values have been established. Therefore, in this study the sealing coat shal be seated inside the ash dyke.

Futhermore rainafall collection sysytem shall be constructed as follows;

- drainage canal around the ash disposal area
- ditch in ash disposal area
- ditch for surface water
- ditch for groundwater
- stormwater reservoir for flood control

5.3.4 Coal Storage Yard

The coal storage yard shall be the outdoor type which has the following conditions. Though, Stockpiles shall be coverd by shed to preven wetting of coal due to rain during rainy season.

(1) Maximam capasity : About 510,000 t（for 30 days of consumption, PLF90%）

(2) Scale of coal storage pile : Width 45 m, Length 500 m, 4 piles

(3) Stacker and Reclaimer Foundation : 2 lines

Considering the load of stock pile and ground condition to predict the settlement and circular slip, apprppriate ground improvement shall be carried out. The foundation of stacker and reclaimer shall be piles.

5.3.5 Buildings and Other Facilities

(1) Power house

1) General

In this project (2×660MW Thermal power plant), Power House Building shall consist of the following Houses and Buildings. Turbine House shall be enclosed by cladding for maintenance. Boiler House shall have roof and not have cladding.

- One no. of common enclosed Turbine House for two T/G units
- Two nos. of Boiler Houses
- One no. of common enclosed Central Control Building for two (2) units;

The following facilities shall be furnished in the Power House:

- Misc. Power and lighting system
- Air conditioning and ventilation system
- Water supply and drainage system
- Sanitary and sewerage system
- Fire detection and protection system
- Lightning protection system

2) Turbine House

The turbine house shall be constructed of closed type fabricated structural steel work.

The structural steel frame will be of rigid type and braced to resist horizontal forces. The field connections of the structural steel will be with high tensile bolts.

Steel sheets roofing and wall shall be coated with PVF and supported by steel frame.

The turbine house shall be supported with spread foundation or pile foundation. Auxiliary equipment such as pumps, tanks and feed water heaters etc. shall be arranged on the reinforced concrete slab in the house. The steam turbine and generator shall be installed on reinforced concrete T/G Block.

3) Boiler House

Boiler, Coal pulverizer, Coal bunker and Auxiliary equipment shall be located in the boiler house. The boiler house shall be constructed of structural steel work with roof. The house shall have roof and sagging wall coated with PVF. The bunker conveyor area shall be surrounded with a roof, a floor and a wall. The ventilation system shall be furnished in the area. The boiler house shall be separated from the turbine house. The boiler house shall be constructed with structural steel frame and reinforced concrete basement.

4) Central Control Building

In the Central Control Building, various facilities for Control/Instrumentation and Electrical equipment shall be located. Central Control Building shall be arranged adjacent to the turbine house.

5.3.6 Chimney

The chimney shall be 150 m high same as the existing chimney. The chimney shall be constructed of tapered cylindrical concrete wind shield. In the shield there are two inside inner flue with acid resistant lining. Chimney shall be supported with spread foundation or pile foundation. Steel platforms on beam grid shall be installed for maintenance of structure as well as for flue gas monitoring. The inner flue shall be supported from platforms horizontally. The inspection access door shall be provided in inner flue at each main platform, for the purpose of inspection of surface condition of inner flue lining. An electrically hoist cage with rack and stairs fixed to the shield shall provide access to all platforms. The lightning protection system shall be located at the top of chimney. The aviation obstruction lights shall comply with the regulation.

5.3.7 Ancillary Building

The following Ancillary Buildings are necessary to suit plant and machinery to be installed, their operation and maintenance.

Coal Unloading & Handling Control Building, ESP & FGD Control House, Ash Handling Building & Ash Slurry Pit, Hydrogen Plant Building, Water Treatment Control House, Waste Water Treatment Plant, Pump House, Administration building, Gate House, Storage, Workshop, Garage etc..

Ancillary Buildings shall be designed in accordance with local regulations and design requirements. Structure for Ancillary Buildings shall be mainly block/brick/reinforced concrete. It's necessary to adopt the structure steel frame for a large span building and a fuel storage building.

CHAPTER 6

ORGANIZATION

CHAPTER 6
ORGANIZATION

6.1 New Power Station Structure

The operation and maintenance structure of a power station generally comprises departments for operation, maintenance, environment, chemistry, fuel management, engineering, etc. The following paragraphs describe the particularly important differences and caution points in ultra-super critical plants compared to general subcritical plants in India at present.

6.1.1 Organization

Figure 6.1-1 shows an example of the organization chart for a new power station with two 660 MW USC plants. In the case of a coal-fired thermal power station of similar size in Japan, approximately 100 staff members are required to conduct operation and maintenance. However, this figure does not include operators who are contracted to conduct actual maintenance work and assist with operation of coal loading and conveyance equipment and flue gas desulfurization equipment and chemical analysis work, as well as power station security personnel, cleaning and general affairs personnel.

Moreover, in line with the application of new environmental controls in India, it is necessary to install flue gas desulfurization equipment in new power stations and to secure personnel for that purpose too.

6.1.2 Main work contents of each organization and establishment of management techniques

The main work contents of each department are as follows.

Operation	:	Operation, monitoring and patrol inspection of main units and other equipment
Maintenance	:	Routine inspections, periodic inspections and maintenance work planning for equipment
Environment	:	Exhaust gas, wastewater, noise environmental management
Chemistry	:	Fuel, water quality and coal ash analyzes
Fuel Management	:	Coal and oil procurement, receiving, storage, issuing, inventory management
Engineering	:	Generation equipment efficiency management, engineering support

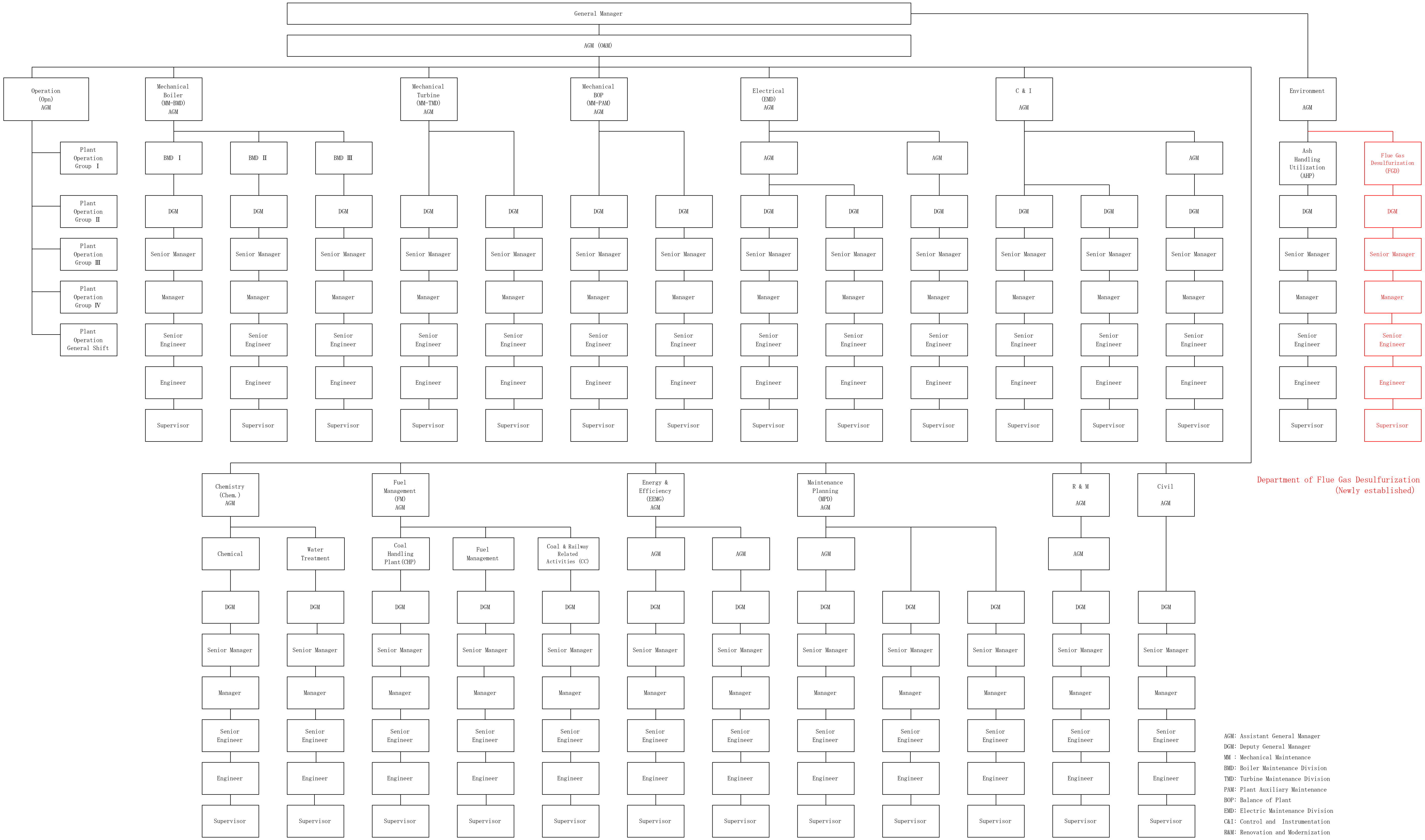


Figure 6.1-1 New Power Station Organization Chart (Draft)

6.2 Examination concerning Operation and Maintenance of the New Power Station

6.2.1 Operation Management

(1) Structure

It will be necessary to monitor operation of the power station 24 hours a day; consequently, operating personnel will need to work in double or triple shifts. Moreover, because the power station will be equipped with flue gas desulfurization equipment, it will be necessary to assign operators for that.

In old power stations, due to the low degree of automation, small operating control rooms are sometimes established for each system, however, in the new power station such control rooms will be integrated to a minimum. From the central control room, it will be possible to monitor operations from each control room as well as operate and monitor all power generation equipment from the central control room and each control room.

(2) Operation

Since the new power station will adopt ultra-super critical once-through boilers, the control system will differ from that used by subcritical drum boilers, which means that the method of operation will also be different. Moreover, in line with new environmental controls in India, it will no longer be possible to discharge wastewater outside of the power station.

The cooling tower and water treatment system, in which particularly important changes have been made, are described below.

1) Cooling tower

In the new power station, clarified water will be used as the main cooling water for condensers. Moreover, since the new environmental controls mean that it will no longer be possible to discharge wastewater outside of the power station, the main cooling water will be circulated and recycled via the cooling tower. Since it is expected that troubles will arise due to the thickening of impurities in line with prolonged use of cooling water, it will be necessary to implement appropriate water quality control consistent with the specifications of equipment. Figure 6.2-1 shows an outline of the cooling tower in the new power station.

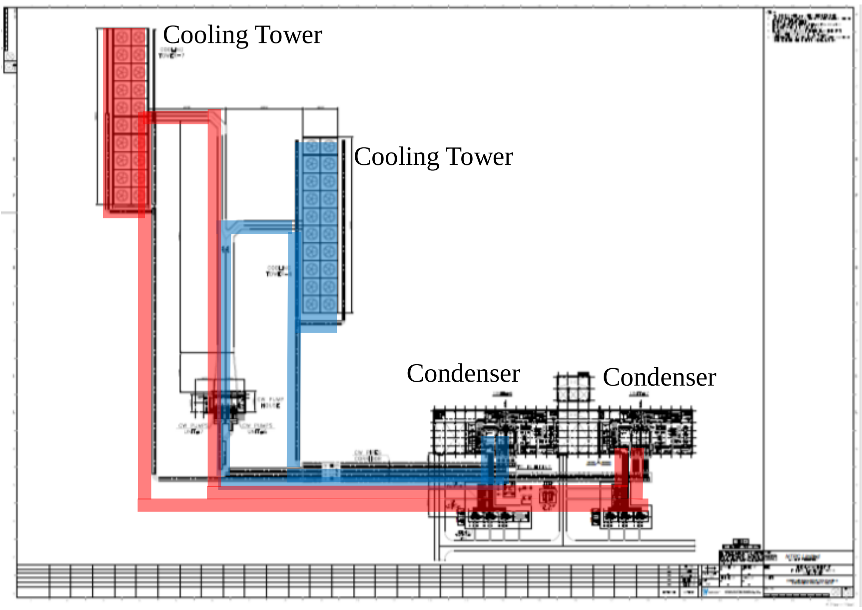


Figure 6.2-1 Outline of Cooling Tower

2) Water quality management

Since the once-through boilers that will be adopted in the project will require higher purity water supply than drum boilers, in addition to introducing condensate demineralization apparatus, water quality management will be an important element. Approaches to controlling water quality in once-through boilers comprise all volatile treatment (AVT) or combined water treatment (CWT). In the project, CWT will be adopted because it can reduce the chemical washing frequency of boilers through slowing down the growth of scale. However, because the magnetite layer that is formed inside pipes by CWT takes longer to stabilize than the hematite layer generated by AWT, operation will be conducted based on AVT will be adopted during unit startup. Table 6.2-1 shows a comparison of the required water quality values in JIS B8223 and the NTPC standard under CWT and AVT. JIS B8223 will be applied for water quality management in the examination here.

Table 6.2-1 Comparison of JIS B8223 and NTPC Standards

Parameters	JIS B8223-2006	NTPC	JIS B8223-2006	NTPC
	CWT	CWT	AVT	AVT
Conductivity (μS/cm)	≤ 0.2	≤ 0.2	≤ 0.25	≤ 0.25
Hydrazine (ppb)	Nil	Nil	10 ≤	10 to 15
pH value (25 degree C)	6.5 to 9.3*	8.0 to 8.5	8.5 to 9.7*	9.0 to 9.6
Oxygen (ppb)	20 to 200	20 to 200	≤ 7	≤ 7
Iron (ppb)	≤ 5*	≤ 10	≤ 10	≤ 10
Copper (ppb)	≤ 2	≤ 2	≤ 2	≤ 2
Silica (ppb)	≤ 20	≤ 20	≤ 20	≤ 20

*Disparity between the JIS B8223 and NTPC standards

6.2.2 Maintenance department

(1) Structure

To ensure the stable operation of the power station and maintenance of performance, it will be essential to implement periodic inspections and routine inspections. It will be necessary to employ experts in machinery, electricity, control, etc. in order to implement inspections and maintenance. Moreover, because flue gas desulfurization apparatus will be installed in the new power station, it will be necessary to assign maintenance staff for that.

(2) Periodic inspections

1) Boiler maintenance

In the boilers, where coal will be combusted to turn water into steam, because boiler tubes will be placed under extremely harsh conditions, various troubles such as abrasion, deformation, degradation and damage will arise. Particularly in ultra-super critical boilers, since high-pressure steam will be sent to the turbines, it will be necessary to appropriately manage the tubes. It will be necessary to examine appropriate inspection intervals and inspection items that consider such points. Troubles will also arise in various forms, the most typical being creep, fatigue, corrosion, erosion, etc. Because the boilers planned here will be designed with higher steam conditions than general subcritical units in order to realize high plant efficiency, service life management with respect to creep will become increasingly important.

In USC plants, high chrome steel is used with respect to higher temperature and higher pressure conditions of use than in conventional plants. Characteristics of high chrome steel that require special attention under conditions of long-term use are: 1) the inverse proportional relation between stress and creep life bends towards the low-strength side, and 2) the strength of welded joints declines greatly compared to the base material. Accordingly, it will be necessary to appropriately assess remaining service life and plan the tube/pipe replacement intervals based on the latest knowledge.

Moreover, in pulverized coal combustion boilers, important elements are the properties of fuel especially the ash content and melting point. In power stations that use coal with high ash content, it is predicted that ash abrasion will advance in the boiler tubes. Therefore, it will be necessary to set inspection intervals and inspection items that take these points into account.

In India, since it is necessary to renew boiler licenses every year based on the Indian Boilers Act, 1923, basic boiler inspections will be implemented once per year. Full-scale inspections will be implemented at appropriate times based on recommendations by the manufacturer. Table 6.2-2 shows typical inspection contents and intervals in Japan.

2) Turbine maintenance

In steam turbines, since high-temperature and high-pressure steam is converted into motive power and the turbine blades are placed under harsh conditions, various troubles such as abrasion, deformation, degradation and damage will arise. Furthermore, efficiency loss due to scale adhesion to the blade will also occur. Although there are no laws and regulations concerning inspections for turbines, it will be necessary to examine inspection intervals and inspection items that take these points into account.

Table 6.2-2 General Periodic Inspections in Coal-fired Thermal Power Stations in Japan

Type	Interval	Period	Main Inspection Items
Class A inspection	Once/4 years	56 days (8 weeks)	Boiler full-scale inspection • Inspection of general boiler, safety valves, etc. Turbine full-scale inspection • All casing open inspection (rotors are removed once every 8 years)
Class B inspection	Once/2 years	42 days (6 weeks)	Boiler full-scale inspection • Same as for the A inspection Turbine basic inspection • Inspection of main valves, condensers, etc.
Class C inspection	Once/1 year	14 days (2 weeks)	Boiler basic inspection • Confirmation of ash abrasion, etc.

(3) Routine inspection

Concerning routine inspections, equipment will be inspected and maintained by appropriately combining condition based maintenance (CBM), time based maintenance (TBM), break down maintenance (BDM) and so on upon considering the importance of equipment, frequency of failures and scope of impact.

(4) Control of spare parts

Stores of spare parts will be held in the materials warehouse of the power station upon considering availability at times of emergencies. In selecting items, decisions will be made upon considering the manufacturers' recommendations and special conditions such as power station location and so on.

(5) Long-term maintenance plan

Upon sorting the experience of periodic inspections and troubles, the schedule for implementing basic inspections, troubleshooting, etc. up until the next boiler full-scale inspection will be compiled.

6.2.3 Performance management

In order to maintain a high-efficiency power station, it is important to organize routine operation data and ascertain the thermal efficiency, in-station efficiency, etc. Moreover, in order to grasp performance over the overall power station and each equipment, it will be necessary to periodically implement performance tests.

6.2.4 Environmental management

Continuous monitoring of NOx, SOx, particulates, etc. in exhaust gas will be implemented at monitoring posts installed in the power station. Regular checks will also be made concerning storm wastewater and noise.

6.2.5 Safety management

Regular patrols will be implemented in order to ensure thorough implementation of safety measures such as use of tag system and helmets, installation of handrails at openings, use of safety belts when working at heights, zoning of work areas and so on.

6.2.6 Education

Concerning the personnel who conduct operation at the new power station, even those who have experience of operating subcritical plants, it will be necessary to first implement introductory training and teach knowledge on the new generating equipment. Moreover, education on general knowledge of power stations, engineering items, safety issues, etc. will be periodically implemented.

CHAPTER 7

CONSTRUCTION PLANNING

CHAPTER 7
CONSTRUCTION PLANNING

7.1 Construction Schedule

Installation schedule of major equipment such as boiler, steam turbine and generator is indicated in Figure 7.1-1 below. Based on the track records of past similar projects in India, we assume the completion of performance guarantee test of Unit1 at 48 months from “Notice To Proceed” including 7 month Mobilization period before the start of civil works. The total construction period is envisaged 54 months from NTP to the end of Unit 2 performance guarantee test as there shall be a 6 month gap between Unit 1 and Unit 2.

Also, the above mentioned schedule does not count the pre-requisite civil works such as access road construction.

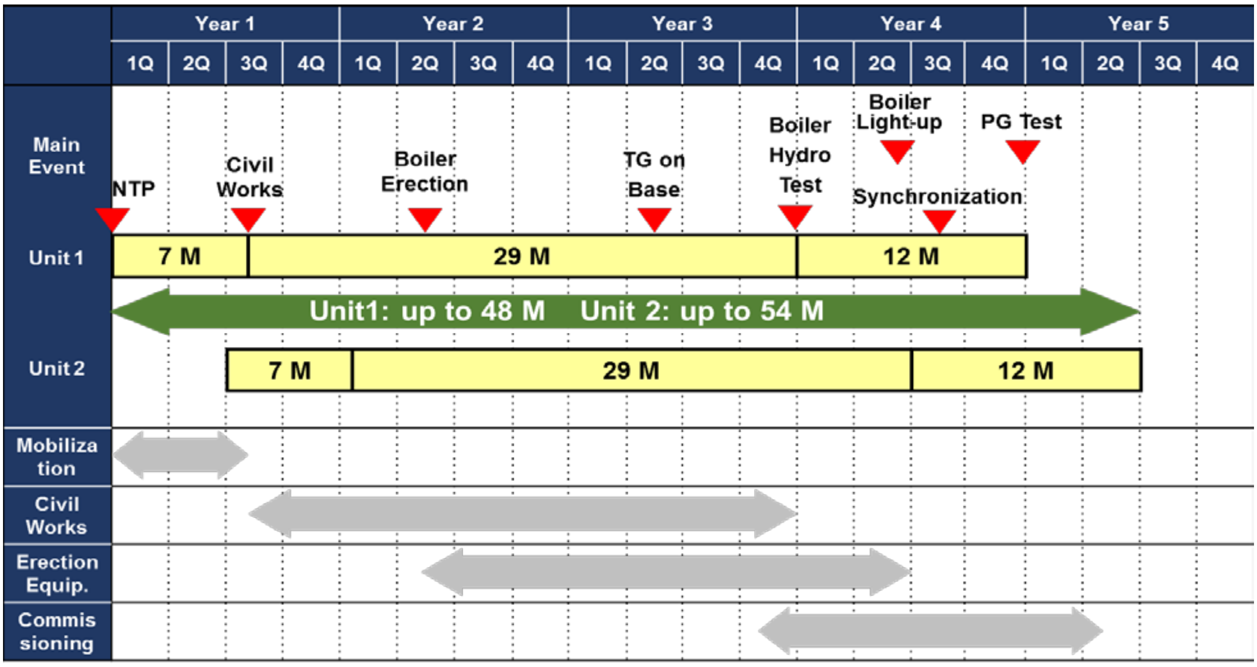


Figure 7.1-1 Indicative Milestone Schedule for Major Equipment

7.2 Pre-construction Schedule

The following assignments are generally required before signing of EPC Contract.

(1) Contractual Preparation and Negotiation required for construction and operation of power plant

Plan, construction and operation of power plant, land acquisition and EIA report are consent by the state/central Government in writing. Preparation of power supply agreement, fuel supply agreement, fuel transport agreement, financing agreement, loan agreement and O&M agreement are required as well.

(2) Detailed Surveys

Soil investigation, water channel surveying, meteorological survey, water quality survey, plot plan, transmission line routing survey, preparation of bid specification, construction plan, budget plan and overall implementation plan and installation of temporary facility for water supply, electricity supply, etc.

(3) Bidding and Negotiation

Preparation of bidding documents (bid invitation, bid formalities, bid schedule), sale of bid specification, evaluation of bids, negotiation of civil and EPC contracts, issueing Notice to Proceed (NTP) to the bid winner

7.3 Project Milestones

EPC construction schedule generally consists of 7 major phases. EPC Contractor shall design, install and inspect based on the contract specification/documents at each phase. Such activities shall be confirmed and approved by the Owner.

(1) Design & Engineering
(2) Manufacturing & Transportation
(3) Erection & Installation
(4) Commissioning
(5) Provisional Handover
(6) Performance Guarantee Test
(7) Guarantee Period (2 years) and Final Acceptance

7.4 Replacing Experience at J-Power's Isogo Thermal Power Plant

Replacement of Isogo Thermal Power Station was conducted as per so called build-scrap-and-build method, where the operation of old units (2 × 265MW) is secured while building the new Unit 1 (600 MW). Once the new Unit 1 becomes operational, old units are no longer required and scrapped. After the demolition work of old plant is completed, construction of new unit 2 (600 MW） take place at the very site.

Source: J-Power Archives

Figure 7.4-1 Birds-eye view of Old Plant

Source: J-Power Archives

Figure 7.4-2 Birds-eye View of New Plant

Historical overview is as follows.

Sep. 1996	Start of Construction work of the New Unit 1
Nov. 2001	Decommissioning of the old Unit 1 & Unit 2
Apr. 2002	Commencement of commercial operation of the New Unit 1
Mar. 2004	Completion of demolition of old Units
Oct. 2005	Start of Construction of the new Unit 2
Jul. 2009	Commencement of commercial operation of the New Unit 2

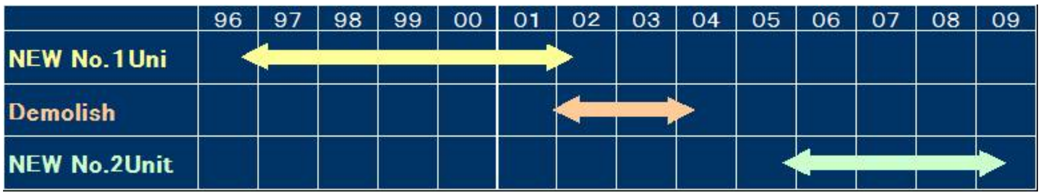
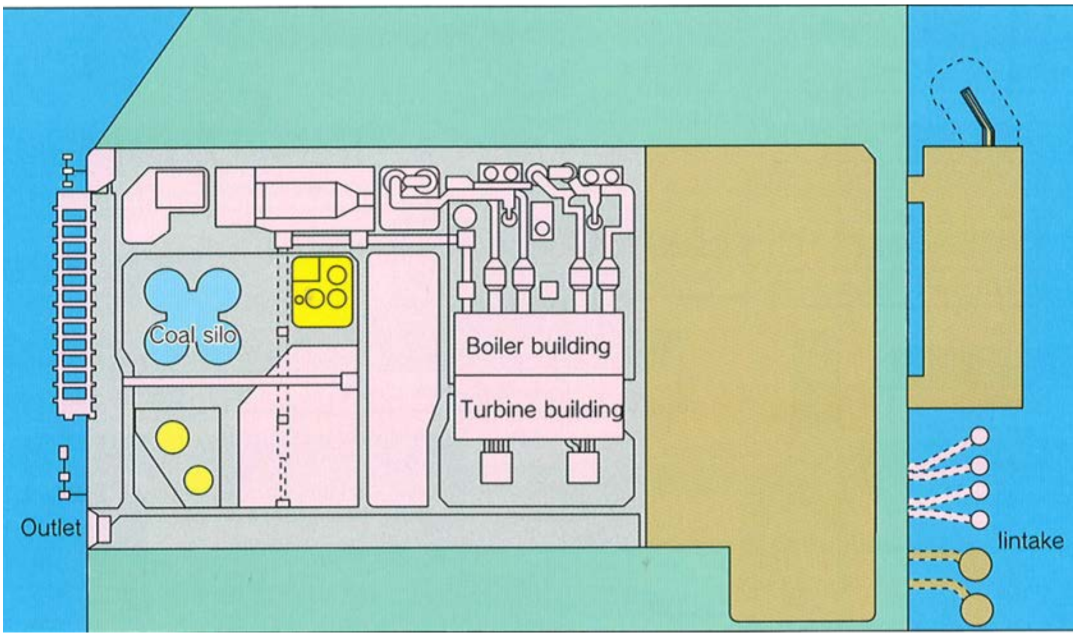


Figure 7.4-3 Historical Record of Replacement Work

7.4.1 Overview of Replacement Process

(1) Securing Space required for New Unit 1 while Old Units Continue to Operate

At first, minimizing of coal storage area, installation of new coal silos, new water treatment plant, new LDO tanks, and demolition of ole LDO tanks were carried out for securing the land for new unit 1.

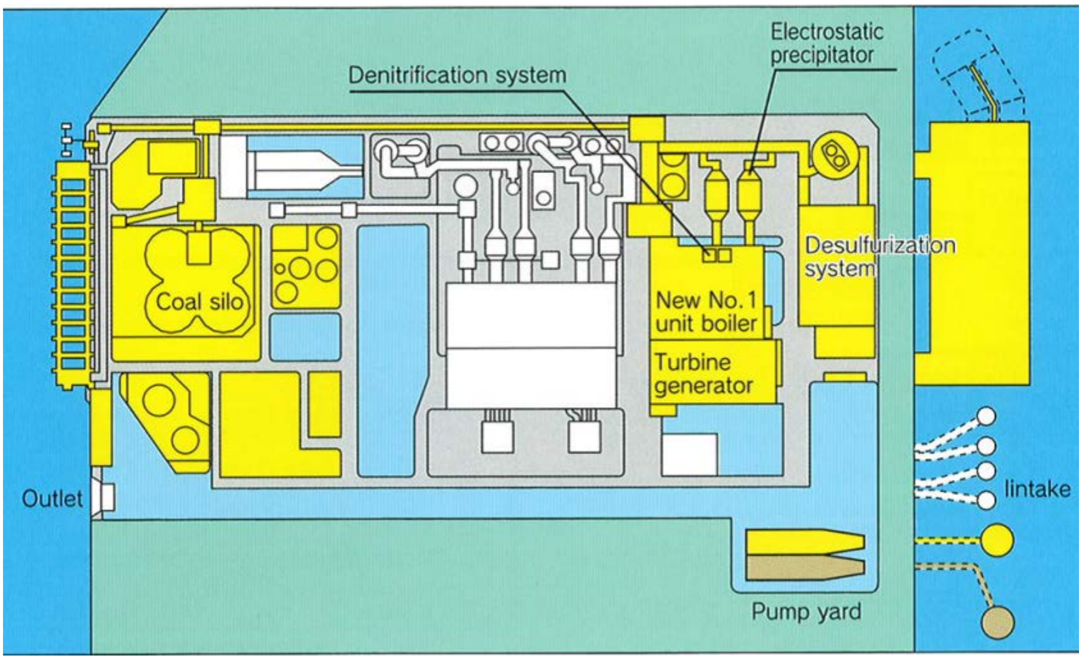


Source: J-Power Archives

Figure 7.4-4 Step 1 – Securing Space for New Unit 1

(2) Construction of New Unit 1

Demolition of old units had started after commissioning of New Unit 1, which was built on the secured space.

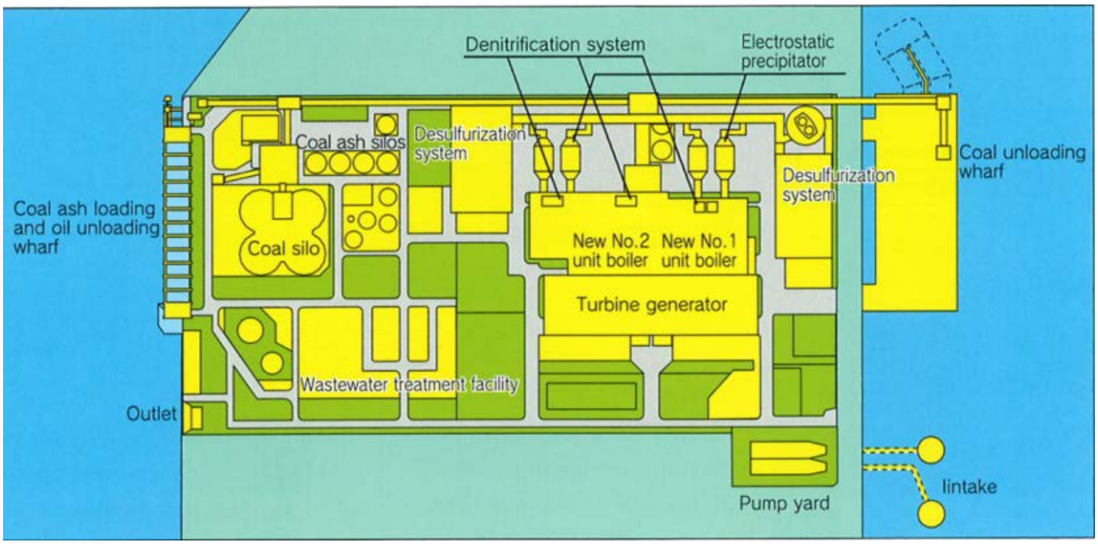


Source: J-Power Archives

Figure 7.4-5 Step 2 – Demolishing Old Units after Completion of New Unit 1

(3) Building New Unit 2

After demolition of old units, New Unit 2 was build.



Source: J-Power Archives

Figure 7.4-6 Step 3 - Construction of New Unit 2

CHAPTER 8

EPC COST ESTIMATION

CHAPTER 8
EPC COST ESTIMATION

8.1 EPC Cost Assumptions

For the proposed power plant, the following assumptions are adopted for EPC cost estimation.

- Base Year ; Fiscal Year 2016
- Classification ; Boiler, Turbine Generator, Environmental Equipment & BOP
- Rated Output ; 2 × 660 MW
- Steam Condition ; Ultra-Super Critical
- Construction Site ; Inland Location
- Main Plant/Ash Disposal Area ; 80ha (200 acre) / 30ha (75 acre), 110 ha (275 acre) in total
- Water Intake ; River Channeling
- Coal Storage Yard ; Outdoor Type (Approx. 30 day operation)
- Other specification ; As described in Chapter 5
- Land Cost ; Not included

8.2 EPC Cost

8.2.1 Turnkey EPC Cost

Estimation results are indicated for with and without DeNOx & DeSOx Systems in Table 8.2-1 below.

Table 8.2-1 Comparison in Costs with and without DeNOx & DeSOx Systems

Item		Turnkey EPC	Turnkey EPC w/o DeNOx & DeSOx
Boiler Island	Cr.	4,719	3,505
TG Island	Cr.	1,600	1,600
BOP	Cr.	2,869	2,869
Civil & Structural	Cr.	1,468	1,268
Total	Cr.	10,656	9,242
unit cost	US$/kW	1,210	1,049

Forex at US$/Rs.66.729 and US$/￥106.43 as on June 9th 2016

8.2.2 Estimation Basis

• Boiler & Env. Equipment	As checked by MHPS
• STG & Electrical Equip.	As checked by Toshiba
• BOP	As checked by DESEIN
• Civil & Structural Works	As checked by J-Power

CHAPTER 9

ENVIRONMENT & SOCIAL ASSESSMENT

CHAPTER 9
ENVIRONMENT & SOCIAL ASSESSMENT

9.1 Existing Environmental Policies/Standards, Applicable laws, and regulations

9.1.1 Introduction

Policies, standards, laws, and regulations for the protection of environment in India are initiated, administered and regulated by the Ministry of Environment, Forests and Climate Change (MoEF&CC), Government of India. Head quartered in Delhi MoEF&CC has its Regional Offices in Bhopal, Bangalore, Bhubaneshwar, Chennai, Chandigarh, Dehradun, Lucknow, Nagpur, Ranchi and Shillong.

Central Pollution Control Board (CPCB) is a statuary body under MoEF&CC and is also located in Delhi. CPCB is primarily responsible for evolving national standards related to Ambient Air Quality and Water Quality under the Water Act, 1974 and Air Act, 1981, and has developed National Standards for Effluents and Emission for various industrial sectors.

Similarly, State Pollution Control Boards (SPCB) have been established by each state in India. These SPCBs generally follow the standards laid down by CPCB. They monitor the quality of effluents and emissions in the industries and ensure their compliance to the standards laid down by the CPCB.

National Green Tribunal has been established in 2010 under the National Green Tribunal Act 2010 for effective and expeditious disposal of cases relating to environment protection and conservation of forests and other natural resources including enforcement of any legal right relating to environment and giving relief and compensation for damages to persons and property and for matter connected therewith.

National Capital Region Planning Board (NCRPB) has been constituted under the Ministry of Urban Development, Government of India, under the NCRPB Act, 1985 to promote balanced and harmonized development of the NCR (National Capital Region) which covers the entire National Capital Territory of Delhi, thirteen districts of Haryana, seven districts of Uttar Pradesh and two districts of Rajasthan.

9.1.2 National Environment Policy

It has been long recognized that natural resources play vital role in providing livelihoods and securing life support ecological services. In order to have sustainable development there is a need for balance and harmony between economic, social and environmental needs of the county. India also plays an important role in several significant international initiatives concerned with the environment.

The National Environment Policy, 2006 has been adopted taking into consideration all these issues.

The dominant theme of this policy is that while conservation of environment resources is necessary to secure livelihoods and well-being of all, the most secure basis of daily conservation is to ensure that people dependent on particular resources obtain better livelihood from the fact of conservation, than from degradation of resource.

9.1.3 Environmental Standards, Regulations etc.

Standards and regulations relevant to the project include

(1) EIA Notification of 14th September, 2006 issued by the MoEF&CC.

According to this notification all industrial and infrastructural development projects included in the schedule of this notification require prior environmental clearance from the competent authority.

The projects have been grouped under categories 'A' and 'B'. Clearance for category 'A' project is given by the MoEF & CC. For category 'B' projects, clearance is given by the State Level Committees set up in each of the States in the country. In order to obtain environmental clearance, EIA study is to be carried out based on the terms of reference issued by the concerned authority in the MoEF&CC or in the State, as the case may be.

The 2 × 660 MW Coal based thermal power project comes under the category 'A' and hence requires clearance from the MoEF & CC.

(2) Consent to Establish

The thermal Power project also requires permission from the concerned State Pollution Control Board (SPCB) for consent to establish and consent to operate under the Air Act and Water Act, for which SPCBS generally follow the standards laid down by the CPCB.

(3) MoEF Notification dated 16th November, 2009.

National Ambient Air Quality Standard was modified vide this notification (**Annexure-I**) with the requirement of separately monitoring $PM_{2.5}$ and PM_{10} for particulate matters. Monitoring of ozone, benzene and some other parameters were added in the list.

(4) MoEF Notification dated 7th December, 2015.

The Ministry, vide this notification (**Annexure-II**), has made stringent provision for the thermal power plants. Stack emission has been restricted to 100 mg/Nm^3 for NOx as well as for SO_2. Particulate matter emission is now restricted to 30 mg/Nm^3.

Water consumption is now restricted to 2.5 m^3/ MW. In view of this stringent standard, provision for FGD and SCR has become mandatory.

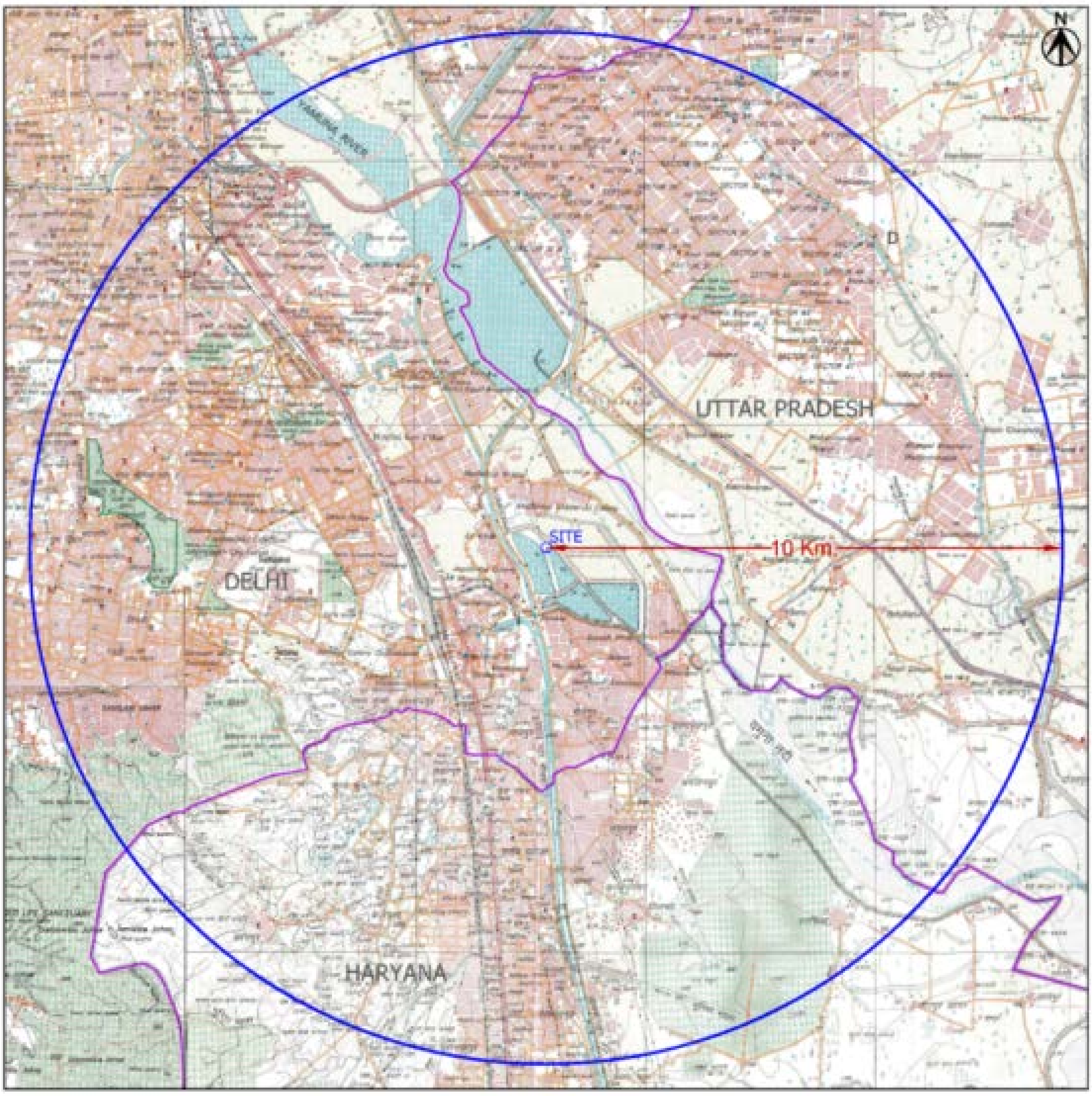
9.2 Present Environmental and Social Status

9.2.1 Site and Surrounding

This chapter describes the existing environmental conditions of the study area, covering an area within 10 km radius around the proposed 2 × 660 MW Badarpur Thermal Power Project. The information provided is based mostly on an EIA report prepared earlier for this site. (Reference: Draft Environmental Impact Assessment Report for Badarpur CCPP- NTPC- 2010)

(1) Topography

The study area is generally plain with slight undulation. The topography of the project site is fairly plain land having an average elevation of 211 m above MSL. Land will be required to be dressed up. (Figure 9.2-1)



Source: Survey of India Toposheet, Govt. of India (1:50,000), Base Map No. H43X6

Figure 9.2-1 Study Area Base Map

(2) Physiography

The physiographic units in Delhi can be categorized as follows:

- Masudpur-Wazirabad Ridge
- Older Alluvial Plain
- Yamuna Flood Plain

The study area falls under Yamuna Flood Plain. The elevation of study area varies from 210 m to 219 m above the mean sea level.

(3) Climate

The climate of the region is semiarid type, with three well defined seasons. Winter starts in November and peaks in January. Delhi is notorious for its heavy fog during the winter season.

In December, visibility is reduced to nearly zero disrupting road, air and rail traffic in the city. During the summer season, the city faces extreme power and water shortage when the demand for these utilities is at its peak. Every year, the heat wave in summer claims several lives in Delhi. The temperature is usually between 21.1°C and 40.5°C during these months. The city, however, has a pleasant climate from February to April and from August to November.

Winters are usually cold and night temperatures often fall to 6.5°C (mean) during the period from December to February. The average annual temperature recorded in Delhi is 31.5°C based on the records over the period of 70 years maintained by the Meteorological Department.

About 87% of the annual rainfall is received during the monsoon months June to September. The rainfall varies from 400 mm to ~ 1,000 mm. On an average, rain of 2.5 mm or more falls on 27 days in a year. Of these, 21.4 days are during monsoon months. For design considerations, rainfall intensity of 20 to 30 mm which generally occurs in one hour duration may be taken into account.

The environment related data was collected from secondary sources like Forest Department of Government of Delhi, published journals and electronic media, India Meteorological Department (IMD), Central Ground Water Board (CGWB), Water Resource Department of Government of Delhi, etc.

9.2.2 Land Use

Land is the most vital resource for sustenance of life and land degradations due to industrialization; urbanization and population growth is a matter of concern. Therefore, it is necessary to establish the existing land use pattern to optimize the land use as well as minimize degradation due to the developmental activities.

The objectives of the present study are:

- To map the study area with respect to various land use/land cover categories
- To identify the sensitive areas within 10 km radius around the project site.

(1) Land Use/Land Cover Classification Based on Satellite Imagery Method of Data Preparation

The land use/land cover as per the study conducted by NTPC is presented in the form of a map prepared by using LANDSAT 7 ETM+ satellite imagery of November 2006. The satellite data was processed using ERDAS Imagine 9.1 software supported with ground checks and ground truth verification. Area and distance calculations have been carried out using GIS software after geo-referencing the interpreted data with the help of Survey of India toposheet of scale

1:50,000. Maps depicting major land use/ land cover classes under various categories are presented Figure 9.2-2

1) Area under Different Land Use

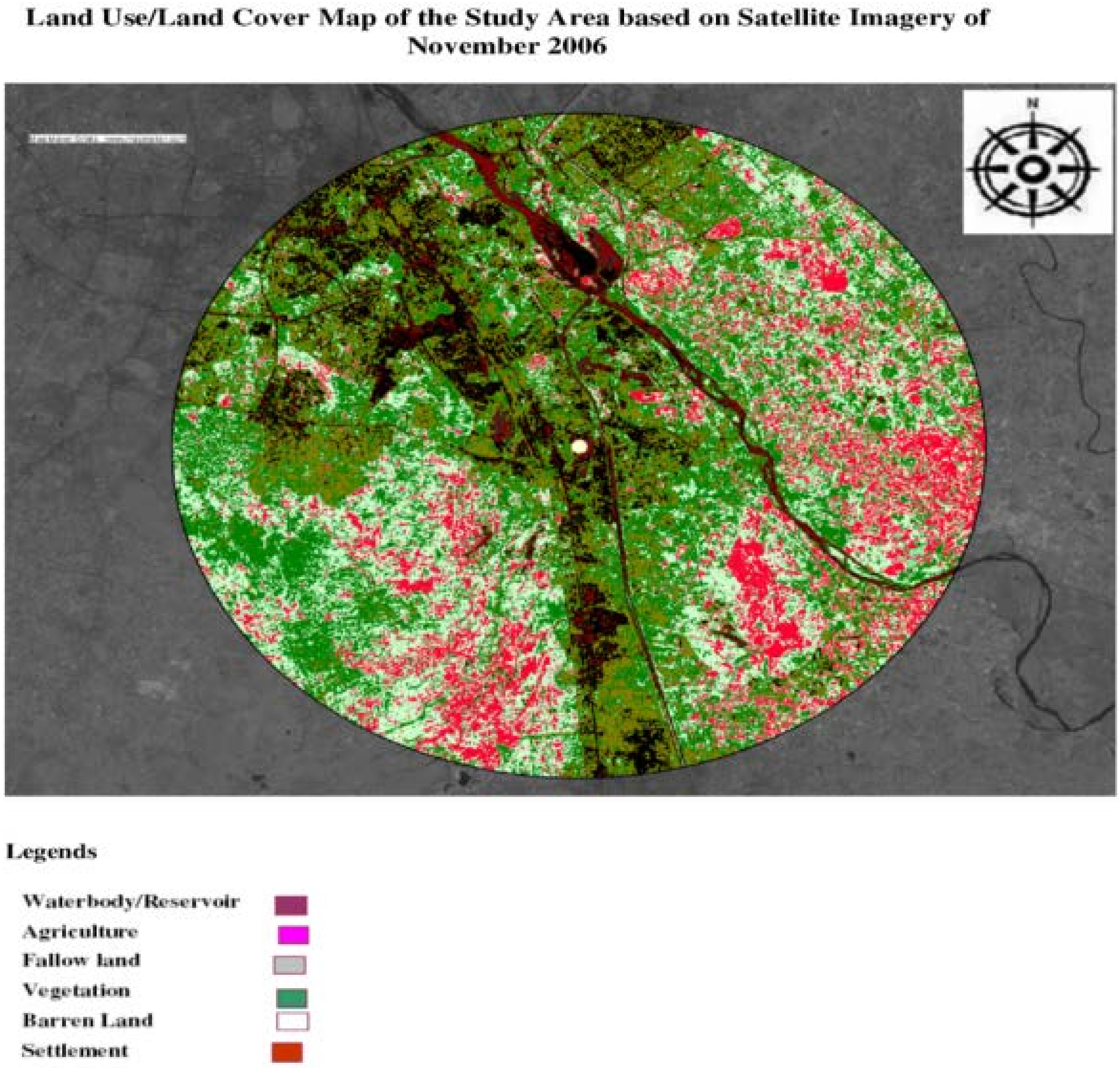
The land use classes with the areas falling under the respective classification are presented in Table 9.2-1.

The data indicates that the area is predominantly occupied by settlements (urban).

Table 9.2-1 Land Use/Land Cover of the Study Area Based on Satellite Imagery (November 2006)

Sl. No.	Land Use Class	Area in	Ha %
1	Agriculture	5,714.80	18.20
2	Waterbody	722.20	2.30
3	Settlements	13,062.40	41.60
4	Vegetation Cover	2,574.80	8.20
5	Fallow land	2,747.50	8.75
6	Waste Land	879.20	2.80
7	Miscellaneous	5,699.10	18.15
Total		**31,400.00**	**100.00**

Source: Draft Environmental Impact Assessment Report for Badarpur CCPP- NTPC



Source: Processed from Satellite imagery “**Landsat ETM+**” www.landcover.org

Figure 9.2-2 Land Use/Land Cover Map of the Study Area based on Satellite Imagery of November 2006

(2) Land Use Classification Based on Census Records

In traditional revenue records in India, major land use classes are; (a) Hills and rocky land, (b) Forests, (c) Pastures (d) Habitated areas (e) Cultivated areas (f) Culturable wasteland (g) Un-culturable wasteland. As per the Census Records of 2011, the study area falls under NCR covering Delhi, Faridabad and Gautam Budh Nagar. As per the census records, the study area is predominantly urban in character.

In census records total land of a village is classified in two categories (a) Culturable land (b) Un-culturable land. Culturable land is further sub-classified into cultivated area and culturable wasteland. Un-culturable land includes habitated area, forest and pastures land covered by roads and buildings

Summary of land use pattern is presented in Table 9.2-2

Table 9.2-2 Summary of Land Use Pattern in the Study Area

(Source: Census Records of 2001)

(Area in ha)

Sl. No.	Land Use Class	Area in Ha	%
I	Forest Land	253.78	0.73
II	Cultivated Land	10,359.97	29.80
	(i) Irrigated	8,476.37	81.82
	(ii) Unirrigated	1,883.60	18.18
III	Culturable Wasteland	4,276.10	12.30
IV	Area Not Available for Cultivation	19,875.15	57.17
	Total Area	**34,765.00**	**100**

Source: Draft Environmental Impact Assessment Report for Badarpur CCPP- NTPC

The total area of land falling in the study area of 10 km radius is 34,765 ha spread over the urban area of Delhi, Faridabad and Gautam Budh Nagar.

9.2.3 Social Environment

The study area of 10 km radius around the Badarpur Power Plant covers South Delhi District in Delhi, Faridabad and Tilpat towns of Faridabad tehsil in Haryana and four towns, namely Noida, Salarpur Khadar, Greater Noida and Dankaur of Gautam Budh Nagar (GBN) district in Uttar Pradesh. As per the census records, the study area is predominantly urban in character.

(1) Study Methodology

This study is mainly based on the review of District Primary Census Statistical Handbook of South Delhi, Faridabad and Gautam Budhha Nagar (GBN) Districts for the year 2011. Census records of the study area have been compiled and analyzed with respect to demography, Sex Ratio, social structure, community structure, educational facilities, health facilities, occupational structure and other infrastructure facilities.

(2) Demographic Profile of the Study Area

1) Distribution of Population

As per 2011 census in the study area 4,932,939 persons inhabited in the 10 km radius study area. Out of which 2652612 are male and 2,280,327 are female. Total number of households in the study area is 1,048,119. The distribution of population is shown in Table 9.2-3**.**

Table 9.2-3 Distribution of Population in Study Area

S. No.	District/Tehsil/ Towns	Total Household	Total Population	Male	Female	Total Population below 6
1.	South Delhi	574,133	2,731,929	1,467,428	1,264,501	331,043
2.	Faridabad Tehsil	294,767	1,434,564	765,657	668,907	190,677
3.	Towns(4) of GBN	179,219	766,446	419,527	346,919	104,496
Total		**1,048,119**	**4,932,939**	**2,652,612**	**2,280,327**	**626,216**

Source: District Primary Census Hand Book-South Delhi, Faridabad and GBN, 2011

(3) Gender Ratio

The configuration of male and female indicates that the male and female constituted about 53.77% and 46.23% of the total population respectively. Gender ratio on an average is 854 female per 1,000 male in the region. The gender ratio for population below 6 years is 862. Table 9.2-4 depicts the detailed description of the female and children population and the gender ratio.

Table 9.2-4 Distribution of Gender Ratio in the Study Area

S. No.	District/ Tehsil/ Towns	Gender Ratio	Gender Ratio of Population below 6 yrs.
1.	South Delhi	862	885
2.	Faridabad	874	845
3.	Towns(4) of GBN	827	856
Total		**854**	**862**

Source: District Primary Census Hand Book-South Delhi, Faridabad and GBN, 2011

(4) Social Structure

Scheduled Castes (SC) constitutes 13.94% of the total population of the study area. There is no tribal population in South Delhi and Faridabad. Table 9.2-5 indicates that a considerable share of population belongs to Schedule castes especially within the 10 km radius of the study area.

Table 9.2-5 Distribution of Population by Social Structure

S. No.	District/ Tehsil/ Towns	Scheduled Caste	SCs (%)	Scheduled Tribe	STs (%)
1.	South Delhi	422,926	15.48	0	0
2.	Faridabad Tehsil	151,414	10.55	0	0
3.	Towns(4) of GBN	58,595	7.64	1,886	0.25
Total		**632,935**	**12.83**	**1886**	**0.25**

Source: District Primary Census Hand Book-South Delhi, Faridabad and GBN, 2011

(5) Literacy Levels

Literacy is one of the most significant indicators of human and social development. Average literacy rate is 74.86%. The female literacy rate is much lower (69.45%) than the male literacy rate (79.52%). Table 9.2-6 indicates the gender-wise literacy rate of the people.

Table 9.2-6 Distribution of Literates and Literacy Rates

S. No	District/ Tehsil/ Towns	Total Literacy	Male Literacy	Female Literacy	Total Literacy %	Male %	Female %
1	South Delhi	2,078,402	1,185,036	893,366	76.08	80.76	70.65
2.	Faridabad tehsil	1,042,893	593,451	449,442	72.70	77.51	67.19
3	Towns(4) of GBN	571,694	330,875	240,819	74.59	78.87	69.42
Total		**3,692,989**	**2,109,362**	**1,583,627**	**74.86**	**79.52**	**69.45**

Source: District Primary Census Hand Book-South Delhi, Faridabad and GBN, 2011

(6) Occupational Structure

The study area is urban in nature, a very few percentage of workers are engaged in cultivation, agricultural labour and household industries in all districts. Of the total 4.9 million Populations, 1.7 million constitute the working population. As per the census definition main workers are those who have worked for six months or more during the last one year in any economically productive activity. Marginal workers are those who are productively involved in any economic activity for 3 months or less but less than six months. Non-worker is one who has not worked at all in any economically productive activity. The main, marginal and non-workers in the total population is 31%, 3.2% and 65.8% respectively. Out of the total working population, 90.8% are main workers and rest 9.2% are marginal workers. The occupational structure is presented in Table 9.2-7

Table 9.2-7 Profile of the Workers in the Study Area

S. No	District/ Tehsil/ Towns	Total Workers	Total Workers		Non Workers
			Main Workers	Marginal Workers	
1.	South Delhi	924,393	869,086	55,307	1,807,536
2.	Faridabad Tehsil	471,111	409,907	61,204	963,453
3.	Towns(4) of GBN	291,559	252,191	39,368	474,887
Total		**1,687,063**	**1,531,184**	**155,879**	**3,245,876**

Source: District Primary Census Hand Book-South Delhi, Faridabad and GBN, 2011

Consistent with urbanizing trends, the primary sector comprising farming and cultivation remains insignificant with only 2.4% worker engagement. More than 93 percent of total working population is engaged in other activities. The type of workers that come under this category include all government servants, municipal employees, teachers, factory workers, plantation workers, those engaged in trade, commerce, business, transport, banking, mining, construction, political or social work, priests, entertainment artists, etc. Infact, all those workers other than cultivators or agricultural labourers or household Industries are other workers. A detailed Classification of the Workers is presented in Table 9.2-8**,** Table 9.2-9**.**

Table 9.2-8 Classification of the Workers in the Study Area

S. No	District/ Tehsil/ Towns	Total Workers	Cultivator	Agricultural Labours	Household Industries	Others
1.	South Delhi	924,393	2,984	5,908	25,081	890,420
2.	Faridabad tehsil	471,111	5,286	11,449	26,858	427,518
3.	Towns(4) of GBN	291,559	6,685	7,270	15,155	262,449
Total		**1,687,063**	**14,955**	**24,627**	**67,094**	**1,580,387**

Source: District Primary Census Hand Book-South Delhi, Faridabad and GBN, 2011

Table 9.2-9 Percentage-wise Classification of the Workers in the Study Area

S. No	District/ Tehsil/ Towns	Total Workers	Cultivator	Agricultural Labours	Household Industries	Others
1.	South Delhi	33.8	0.3	0.6	2.7	96.3
2.	Faridabad tehsil	32.8	1.1	2.4	5.7	90.7
3.	Towns(4) of GBN	38	2.3	2.5	5.2	90
Total		**34.2**	**0.9**	**1.5**	**4**	**93.7**

Source: District Primary Census Hand Book-South Delhi, Faridabad and GBN, 2011

(7) Infrastructure Facilities

The Infrastructure facilities available in the study areas are described in this section.

1) Educational Facilities

Since the settlements are urban in nature the educational facilities in the district is well developed. The educational facilities are evenly distributed in the area. In all, there are 126 primary schools, 87 middle schools, 52 high schools and 47 higher secondary schools in south Delhi District. The available educational facilities of Faridabad and Towns of Gautam Buddha Nagar are given in Table 9.2-10.

Table 9.2-10 Educational Facilities in the Study Area

S. No	District/ Tehsil/ Towns	Primary School	Middle School	Secondary School	Sr. Sec. School
1	South Delhi	126	67	52	47
2	Faridabad tehsil	267	57	57	57
3	Towns(4) of GBN	316	68	132	49
Total		**709**	**192**	**241**	**153**

Source: District Primary Census Hand Book-South Delhi, Faridabad and GBN, 2011.

There are 10 recognized vocational training institutes and 1 polytechnics functioning in South Delhi District. Faridabad tehsil is having 5 polytechnics and 2 recognized Shorthand, Typewriting and vocational training institutions. There is 1 recognized Short and, Typewriting and vocational training institutions and no polytechnics in Gautam Buddha Nagar. The available higher educational facilities are given in Table 9.2-11.

Table 9.2-11 Higher Educational Facilities in the Study Area

S. No	District/ Tehsil/ Towns	Arts/ Science/ Commerce colleges	Medical colleges	Engineering colleges	Management Institute/ colleges
1	South Delhi	143	307	199	144
2	Faridabad tehsil	2	0	3	3
3	Towns(4) of GBN	1	1	13	5
Total		**146**	**308**	**215**	**152**

Source: District Primary Census Hand Book-South Delhi, Faridabad and GBN, 2011

2) **Health Facilities**

South Delhi has the advantage of possessing large number of medical institutions with the best specialisations in almost all the fields available in the country. There are 11 maternity homes, 5 maternity and child welfare centers, 4 Family Welfare Center and 4 Nursing Homes in South Delhi district, Faridabad tehsil and 4 towns of Gautam Buddha Nagar. Detailed health facilities are given in Table 9.2-12**,** Table 9.2-13**.**

Table 9.2-12 Health Facilities in the Study Area (Continued..)

S. No	District/ Tehsil/Towns	Family Welfare Center	Maternity and Child Welfare Center	Maternity Homes	Nursing Homes
1.	South Delhi	1	2	2	3
2.	Faridabad tehsil	1	1	8	0
3.	Towns(4) of GBN	2	3	1	2
Total		**4**	**5**	**11**	**5**

Source: District Primary Census Hand Book-South Delhi, Faridabad and GBN,2011

Table 9.2-13 Health Facilities in the Study Area

District/ Tehsil/ Towns	Hospitals (Allopathic & Others)	Dispensary/ Health Center	Veterinary Hospital	Mobile Health Clinic	Charitable Hospital/ Nursing Home	Medicine Shop
South Delhi	2	21	3	3	16	163
Faridabad tehsil	7	35	1	1	3	916
Towns(4) of GBN	3	1	5	6	9	127
Total	**12**	**57**	**9**	**10**	**28**	**1,206**

Source: District Primary Census Hand Book-South Delhi, Faridabadand GBN, 2011

(8) Water Resources

In South Delhi and Gautam Buddha Nagar (GBN), the main sources of water supply for the households are Tap water from treated sources, Tap water from un-treated sources, hand pumps and Tubewells/Boreholes. Overhead tank and Tubewell/Boreholes are the main sources of water supply in Faridabad tehsil.

(9) Transport & Communication Facilities

The project area is well connected with bus routes and railway networks. Buses are the most popular means of road transport. Personal vehicles especially cars also form a major chunk of vehicles plying on Delhi roads. Taxis, auto rickshaws and cycle rickshaws also ply on South Delhi roads in large numbers. Nearest railway station is Tuglakabad, Hazarat Nizamuddin, old and New Delhi railway station in Delhi and Faridabad station in Faridabad tehsil and Ghaziabad railway station Dankaur and Dadri station in Gautam Buddha Nagar District. The Delhi Metro is a rapid transit system serving Delhi, Faridabad, Noida and Ghaziabad in the National Capital Region of India. The nearest airport is Indira Gandhi International Airport at Palam.

(10) Industry and Banking

The three significant industries operating in nearby towns like Kotla Mahigiran, Pul Pehlad, Taj Pul, Mithepur, Molar Band, Aali, Jaitpur are furniture making, Jari Work and Iron work in south Delhi district. On the other hand three most important commodities manufactured in industries at Faridabad towns are tractors, fridge and JCB crane.

Gautam Budhha Nagar has significant numbers of manufacturing industries which produces commodities like cement, iron tools, rice, crockery, water tank, readymade garments bulb, plastic bags, carpets, cotton sheet, clay pots, footwear industries, locks sweets and boutique. Other manufacturing units like electrical products, Honda workshop, assembling of Holland tractors.

There are 30 National Banks, 17 Private Banks and 1 Cooperative Bank operating in South Delhi Towns. Gautam Buddha Nagar towns and Faridabad tehsil are having significant numbers of National Banks, Private Banks, Cooperative Bank, agriculture credit societies and Non-agriculture credit societies are functioning in. Table 9.2-14 depicts the Banking status in the Study Area

Table 9.2-14 Banking Facilities in the Study Area

District/Tehsil/ Towns	Nationalised Bank	Private Commercial Bank	Co-operative Bank	Agricultural credit societies	Non-agricultural credit societies
South Delhi	30	17	1	0	0
Faridabad Tehsil	28	17	2	3	34
Towns(4) of GBN	23	14	2	3	4
Total	**81**	**48**	**5**	**6**	**38**

Source: District Primary Census Hand Book-South Delhi, Faridabad and GBN, 2011

(11) Sanitation & Drainage facilities

There is open drainage system in most of the town except Saidabad, Pul Pahlad and Molar band town where both open and closed drainage facilities are available in south Delhi.

171,200 number of Flush/Pour Flush (Water borne) latrines are available in the area. In Gautam Buddha Nagar towns and Faridabad tehsil also, they have open drainage system as well as open and closed drainage facilities. There is 143,552 and 57,200 Flush/Pour Flush (Water borne) latrines and 112,377 and 1,320 pit system are available in the Faridabad tahsil and Gautam Buddha Nagar towns respectively.

9.2.4 Cultural and Heritage aspects

The south Delhi district has rich cultural heritage. The famous historical monument and place of tourist interest Qutab Minar, is located in this district. Other famous historical monuments and places of tourist interest include Tughlaqabad Fort, Deer park, ISKCON Temple, Bahai (Lotus Temple) and Chattarpur Mandir.

Surajkund Crafts Mela is an annual fair celebrated in Faridabad District, Haryana. Surajkund was a simple tourist destination but it has now became famous site for this annual exhibition of the centuries old crafts and traditions of India. The festival showcases the art, craft and cuisines of India. The crafts persons from SAARC nations also participate in this Fair. The Mela is located at a distance of 8 km from south Delhi in the historic site of Surajkund. The ancient Sun Temple stood here during AD 1000 as per the available records.

9.2.5 Community Health

On community health status, the Non-communicable diseases are a major public health problem among the middle and upper middle class families in the urban area due to changing life style, increasing stress and tensions due to changes in social and cultural systems in the society. Communicable diseases such as Tuberculosis, asthma, fever, jaundice and dengu are most commonly found illness among the lower and lower middle class families in the study area. The main reasons are overcrowed residential/commercial areas and inefficient municipal solid waste handling.

Other factors like increase in life expectancy, resulting primarily from decline in child mortality, control of infectious diseases, extensive use of antibiotics, improvement in nutritional standards and access to health services, etc. have also contributed to increase in life expectancy in the population. With increase in the number of aged population, it is expected that there will be higher incidence and prevalence of diseases like Hypertension; IHD, Diabetes, Cancers and range of geriatrics problems.

In this changing scenario, there is a need for strengthening of government hospitals and affordable health centers to cater the needs of local populace in urban/fringe area.

9.2.6 Hydrology

(1) Surface Hydrology

Hydrology of the study area is broadly described under following categories:

1. Surface water hydrology: rivers, stream, canal, ponds *etc.*
2. Ground water hydrology: accumulation in deeper strata of ground.

The only source of recharging for surface water and ground water is from precipitation (rainfall). The long term average total rainfall is 1,053 mm. In Delhi too ground water contributes to substantial quantity of supply. Especially in new development areas ground water is largely being utilised as a drinking water resource, mainly because of the insufficiency of the Yamuna water share for Delhi. Ground water collects in the aquifers over thousands of years through infiltration and ground water flow recharge. A particular amount of ground water is replenished regularly through rainwater infiltration.

Sustainable use of ground water means withdrawal of ground water at a rate at which it is replenished through recharge. Faster withdrawal rates would lead to fall in water table and finally depletion of ground water.

The study area is mainly drained by River Yamuna at a distance about 2.0 km from Badarpur flowing from Northwest to Southeast direction. The active flood plain aquifer system occupies an area of 97 Sq.km and stretches about 35 km along river Yamuna. The Agra Canal lies at a distance of 1Km in the East from Badarpur site.

1) Yamuna River Basin

The river Yamuna, a major tributary of river Ganges, originates from the Yamunotri glacier near south western slopes of Banderpoonch peaks in the Mussourie range of the lower Himalayas at an elevation of about 6,387 meters above mean sea level in district Uttarkashi (Uttrakhand). It travels a total length of 1,376 kilometers (855 miles) and has a drainage system of 366,223 km^2, 40.2% of the entire Ganges Basin, before merging with the Ganges at Triveni Sangam, Allahabad. In its first 170 km stretch, the tributaries Rishi Ganga Kunta, Hanuman Ganga, Tons and Giri join the main river.

Arising from the source, river Yamuna flows through a series of valleys for about 200 Kms, in lower Himalayas and emerges into Indo-Gangetic plains. In the upper eaches, the main valley is overlooked by numerous hanging valleys, carved by glaciers during the last ice ages. The gradient of the river is steep here and the entire geomorphology of the valley has been influenced by the passage of the river. In the upper stretch of 200 km, it draws water from several major streams.

It crosses several states, Uttarakhand, Haryana and Uttar Pradesh, passing by Himachal Pradesh and later Delhi, and meets several of its tributaries on the way, including Tons, its largest and longest tributary, Chambal, which has its own large basin, followed by Sindh, the Betwa, and Ken. Most importantly it creates the highly fertile alluvial, Yamuna-Ganges Doab region between itself and the Ganges in the Indo-Gangetic plain. Nearly 57 million people depend on the Yamuna River, with an annual flow of about 10,000 billion cubic metres and usage of 4,400 bcm (of which irrigation constitutes 96 %), it accounts for more than 70% of Delhi's water supply.

The water flowing in the downstream of Wazirabad barrage is the untreated or artially treated domestic and industrial wastewater contributed through several drains along with the water transported by Haryana Irrigation Department from Western Yamuna Canal (WYC) to Agra Canal via Nazafgarh Drain and the Yamuna. After 22 km downstream of Wazirabad barrage there is another barrage, Okhla barrage, through which Yamuna water is diverted into Agra Canal for irrigation. No water is allowed to flow through barrage during dry season. Whatever water flows in the river beyond Okhla barrage is contributed through domestic and industrial wastewater generated from East Delhi, Noida and Sahibabad and joins the river through Shahdara drain. The Yamuna after receiving water through other important tributaries joins the river Ganga and the underground Saraswati at Prayag (Allahabad) after traversing about 950 km. Thus, Yamuna river can not be designated as continuous river particularly in dry seasons (almost 9 months), but can be segmented in five distinguished independent segments due to characteristic hydrological and ecological conditions.

The catchment of Yamuna river system covers parts of Uttar Pradesh, Uttranchal, Himachal Pradesh, Haryana, Rajasthan, Madhya Pradesh & Delhi states.

(2) Ground Hydrology

The ground water availability in the territory is controlled by the hydrogeological situation characterized by occurrence of alluvial formation and quartzitic hard rocks. The ground water occurs in silty to sandy layers of the alluvial sediments. The permeability varies from 0.5 to 8 m/day and transmissivity from 10 to 100 m^2/ day. The hydraulic gradient is approximately 1.3 km/m to 2.0 km/m.

Thickness of unsaturated zone in Tughlaqabad, Okhla, Khanpur, Pushp Vihar, Sainik Farm, Saket, Mehrauli and surrounding areas of Gadaipur, Jaunapur and Ghitorni villages of South district varies from 45 to 50 m. In areas like Greater Kailash- I & II, Chittaranjan Park, Green Park, Lado Sarai and surrounding areas the thickness of unsaturated zone is about 25 m. Vasant kunj, Vasant Vihar, Samalkha and Rajokri areas of South west districts have unsaturated zone thickness ranging from 35 to 45 m. The Central part of South west districts have unsaturated zone of 12 to 15 m. Thus, very potential unsaturated aquifer system is available in these two districts shows that, more and more areas are becoming brackish to saline because of exhaustion of fresh ground water present at shallow depths and upcoming of brackish water into fresh water aquifers.

1) Depth to Hardrock

The Alwar quartzites of Delhi system exposed in the area belong to Pre- Cambrian age. The quartizites are pinkish to grey in colour, hard, compact, highly jointed, fractured and weathered. These occur with interbeds of mica- schists and are intruded locally by pegmatites and quart veins. The strike of these rocks varies north east - south - west to north northeast – south southeast with steep dips towards south east and east except for some local variations due to folding. The prominent joint sets are strike joints, bedding joints and dip joints. Quartzites are ferruginous and gritty types on weathering and subsequent disintegration give rise to coarse sand (Badarpur sands). Chemical weathering of deer horizons is also common.

The exploratory drilling undertaken has brought out the subsurface configuration of rock formation and depth to bedrock is different parts of NCT of Delhi. The nature of bedrock topography is rendered uneven due to existence of sub surface ridges. Thickness of alluvium overlying the quartzites increases away from the outcrops. The thickness of alluvium is 300 m or more in most parts of Najafgarh, Kanjhawala and Alipur blocks while in the south eastern parts of Alipur block, it varies from 100 m to 300 m. In the eastern parts of Najafgarh Block, the thickness range is from 50 m to 300 m. In the city block, west of the ridge, the alluvium thickness increases away from the ridge to 300 m or more. East of the ridge, in the area upto river Yamuna, the alluvium thickness is comparatively less to about 165 m. East of river Yamuna covering parts of city and Shahdara blocks, the thickness ranges from 48 to 240 m. In the Chattarpur basin of Mehrauli block, the alluvial thickness varies from a few metres near the periphery to 115 m around Satbari bund.

2) Status of Groundwater Reserves

The study area is occupied by diversified geological formations consisting of unconsolidated Newer and Older alluvium and Quartzites of Delhi Super Group.

Quartzite rocks which occupy the maximum part of south district, have limited source of availability ground water confining largely to fracture planes and the weathered zone/mantle. Yield potential of the fracture zones varies from 100 to 200 lpm. The older alluvium in the Chattarpur basin consists of predominantly sand with subordinate silt, clay and kankar. Thickness of alluvium is highly variable because of presence of sub surface ridges and faults in the South district. Except along the river Yamuna, Ground water level in the district is declining with rates varying between 1 to 4 m per annum. In few pockets in the district, the rate of decline has been recorded to be 3 to 4 m per annum, which is very alarming.

In the study area, the first layer of clay and kankar extends to depth of 8m bgl. This is followed by a layer of kankar and silt upto 20 m, this is under lain by weathered and fractured quartzites. A comparative study of water level of 1960 and 2002 shows that in study area, the water level which was at 20 to 30m below ground level has gone down to 30 to 45 mts below ground water level.

The depth to water level recorded in NCT Delhi as on date ranges from 1.20 to 67.73 mbgl. The deeper water levels are mostly found in south and south west districts of NCT Delhi. The CGWB data shows that nearly 50% wells of south district shows depth to water level more than 40 meters below ground level (mbgl) and nearly 35% wells show depth to water level in the range of 20 to 40 meters below ground level.

The decadal premonsoon water level data shows that nearly 95% monitoring stations shows decline in water level in the range of 0.08 to more than 20 meters as compared with 10 year mean of May water level. The maximum fall have taken place in district of South and South-West (i.e. 11.01 to 26.55m).

The decline of more than 20 m has been observed in Mehrauli block. In the Chattarpur basin the shallow fresh water aquifers within depth range of 40 - 50 m behave as a single unconfined aquifer system. In Mehrauli 30 to 50 m deep tubewells yield 36 m^3 /hr (8,000 gallons/ hr) to 135 m^3 /hr (30,000 gallons/ hr) for 2.5 to 15m of drawdown.

The Mehrauli block consists of alluvial formation and quartzite ridge. In this block apart from the ridge area where the hardrock occurs at surface and shallow depth, in other areas the bedrock occurs at less than 50 m bgl in many places. In the Chattarpur basin it ranges in depth between 50 to 100 m bgl.

This observation has been further supported by the recent geophysical investigations. To record the extent of water table, water level data were collected from eight selected dugwells/tubewells and borewells.

(3) Hydrogeology

The Ground water availability in the territory is controlled by the hydrogeological situation characterized by occurrence of alluvial formation and hard rocks such as quartzite. The hydrogeological set up and the following distinct physiographic units further influence the ground water occurrence: (1) Older Alluvial Plain on the eastern and western side of the ridge. (2) Yamuna Flood Plain deposits. (3) Isolated and early closed.

Chattarpur alluvial basin. (4) NNE-SSW trending Quartzite Ridge. The yield of tube wells ranges between 18-144 m^3/ hr in Yamuna Flood Plain aquifers. In older alluvium of eastern and western sides of the ridge, the yield of tube wells ranges between 12 to 36 m^3/ hr. Tube wells constructed in Chattarpur alluvial basin tapping the aquifers of both alluvium and weathered and fractured quartzite yield about 9 to 27 m^3 / hr. Discharge of tube wells constructed in Quartzites varies from 6-15 m^3 / hr.

The alluvial deposits are of Quaternary age. The newer alluvium belongs to recent age and is referred to the sediments deposited in the flood plains of Yamuna River. These sediments range in texture from clay/silt mixed with tiny mica flakes to medium/coarse sand and gravel. Newer alluvium, in general, is characterised by absence of kankar.

The older alluvium consists of sediments deposited as a result of past cycles of sedimentation of Pleistocene age and occurs extensively in the alluvial plains of the territory. This is comprised of inter bedded, lenticular and inter-fingering deposits of clay, silt and sand ranging in size from very fine to very coarse with occasional gravels. The kankar or secondary carbonates of lime occur with clay/silt deposits and sometimes as hard/compact pans. Older alluvium is predominantly clayey in nature in major parts of territory except the nearly closed alluvial basin of Chattarpur where the alluvial formation is derived from the weathered quartzites rocks.

The hard rock formations; mainly the Alwar quartzites of Delhi System exposed in the area belong to Pre-Cambrian age. The quartzites are pinkish to grey in colour, hard, compact, highly jointed/ fractured and weathered. These occur with interbeds of micaschists and are intruded locally by pegmatites and quartz veins. The strike of these rocks varies northeast southwest to north-northeast south southwest with steep dips towards southeast and east except for some local variations due to folding. Quartzites are ferruginous and gritty types on weathering and subsequent disintegration give rise to coarse sand (Badarpur sands). Chemical weathering of deeper horizons is also common.

9.2.7 Water Use

(1) Source of Water

The study area is situated in Yamuna sub-basin of the Indo-Gangetic alluvial plains. The river Yamuna, a tributary of the Ganga, flows through the Eastern part of the study area, at a distance of about 2.5 km. from the project site. Yamuna river is the only perennial stream in the study area and main source of water for Delhi. As per the Memorandum of Understanding (MOU) of May 12, 1994, National Capital Territory of Delhi has been allocated 0.724 bcm of Yamuna water annually and minimum flow remains 10 m^3/Sec in the Yamuna river throughout the year down stream at Okhla Headwork to take care of ecology of the river.

(2) Present Water Use in the Study Area

1) Surface Water Use

Surface water contributes to over 86% of Delhi's total drinking water. Yamuna provides the major share of this water. Other sources of drinking water supply to Delhi include the Himalayan rivers through different interstate arrangements and sub-surface sources like Ranney wells and tube wells.

Table 9.2-15 Available Water Resources in Delhi

S.No.	Souece of Water	Quantity(MGD)
1	Yamuna River	339
2	Ganga River	240
3	Bhakra Storage	150
4	Rainy Wells/tube wells (Ground Water)	100
	Total	**829**

Source: Draft Environmental Impact Assessment Report for Badarpur CCPP- NTPC

The Delhi depends on river Yamuna and partially on river Ganga for its share of raw water. For sustainable development of Delhi, it is essentialto ensure adequate supply of water in terms of reliability, quality and quantity. Although Delhi has an average water availability of 225 lpcd, the distribution of the same is not uniform.

The future supply critically depends on the progress of the proposed dams in U.P, Uttarakhand and H.P; Satluj Yamuna Link Canal and Sharda Yamuna Link Canal**.**

2) Ground Water Use

Ground water exploration earlier carried out shows water depth range of 50 to 150 m in the Delhi Quartzite. The Quaternary deposits constitute the major repository of ground water. Total ground water resources in the NCT Delhi are estimated around as 28,156.32 ha (Central GroundWater Board). The annual extraction of ground water is estimated around 47,945.18 ha m (Central Ground Water Board). Table 9.2-16 gives the ground water exploration/sources for Delhi.

Table 9.2-16 Ground Water exploration/sources for Delhi

Sl. No.	Dynamic Sources	Quantity
1	Annual Replenishable Ground Water Resources	0.30 BCM
2	Net Annual Ground Water Availbility	0.28BCM
3	Annual Ground Water Draft	0.48 BCM

Source: Draft Environmental Impact Assessment Report for Badarpur CCPP- NTPC

9.2.8 Geology

(1) General Description of Study Area

The study area basically consists of older alluvium i.e. unconsolidated inter bedded, inter fingering deposits of sand, clay and kankar. It is moderately sorted with variable thickness.

The basement and surface exposure of the hard rock in N.C.T Delhi is occupied by quartzite inter-bedded with mica schist belonging to Delhi Super Group. Unconsolidated sediments of Quaternary to Recent age unconformably overlie Delhi Super group. The quartzite is grey to brownish grey, massive to thinly bedded and structurally form a coaxially refolded regional anticline plunging towards north. The major planar structure strikes NE-SW with steep southeasterly dips. Quartzite occurs in the central and southern part of the area while the Quaternary sediments comprising Older and Newer Alluvium cover the rest of the area. The older Alluvium comprises silt, clay mixed with kankar in varying proportions. The Newer Alluvium mainly consists of un-oxidized sands, silt and clay occurring in the Yamuna flood plain. The thickness of alluvium on eastern and western side of the ridge is variable but west of the ridge it is generally thicker (>300m). The area is dissected by number of faults, fractures and shears, the trend of these varies from NNE-SSW to ENE-WSW.

Geologically, Delhi is located on folded crustal ramp with basement rocks of Delhi Supergroup, bounded by two regional faults viz Mahendragarh-Dehradun Fault in the west and Great Boundary Fault in the East. The ramp trending NNE-SSW across 'fore deep', is juxtaposed to Himalayan thrust belt. Thus, the seismic vulnerability of built environment of Delhi need be examined vis-a-vis high frequency ground motions due to events endemic to faults of Peninsular Domain and also due to frequency content of attenuated events with source zone in thrust domain of Himalayas. Fault lines of consequence in the domain are (i) Mahendragarh Fault, (ii) Great Boundary Fault, (iii) Moradabad Fault and (iv) Sohna Fault. The 1st level microzonation map discretizes the territory of NCT Delhi in 9 units viz. (i) Ridge ambience of exposed rock with low hazard, (ii) Layer of impedance contrast at shallow depth (<30 m) with Moderate Hazard, (iii) Weathered rock zone with Moderate Hazard due to weathering induced pronounced ground response, (iv) Chhattarpur Basin with High Hazard due to anticipated Basin effect, (v) Central Delhi with Moderate Hazard due to amplification in mid frequency level and Basin margin effect (vi) North-West Delhi plains (Bangar) of Moderate Hazard due to thick soil cover, (vii) South Najafgarh sedimentary fill (Dabar) with Moderate Hazard due to high amplification and liquefaction, (viii) Zone of Basin margin effect west of Delhi ridge: High Hazard, (ix) Newer alluvium proximal to Yamuna river: High Hazard due to Liquefaction Potential. Hazard levels have been alluded to different microzones based on anticipated amplification and liquefaction susceptibility.

The Delhi ridge which is the northernmost extension of Aravalli mountain consists of quartzite rocks and extends from southern parts of the territory to western bank of Yamuna for about

35 kilometers. The alluvial formations overlying the quartizitic bedrock have different nature on either side of the ridge. The Yamuna flood plain contain a distinct river deposit. The nearly closed Chattarpur alluvial basin covering an area of about 48 km^2 is occupied by alluvium derived from the adjacent quartzite ridge. The geological units are described below:

- Alluvial plain on eastern and western sides of the ridge
- Yamuna flood plain deposits
- Isolated and nearly closed Chattarpur alluvial basin
- NNE-SSW trending Quartzitic Ridge.

(2) Seismic Zone

Delhi and its surroundings are seismically active. It falls in Seismic Zone IV. Earthquakes of magnitude from 3 to 7.4 have observed in and around Delhi during the past 3 centuries.

9.2.9 Soil

General Characteristics of the Soil in the Study Area

The Yamuna river and terminal part of the Aravalli hills range are the two main geographical features of Delhi. Physiographically, Delhi consists of the Yamuna flood plain, the old Khadar (earlier floodplain), and the Bangar (upper Alluvial plain). Thus, a major part of Delhi is covered by the alluvial soils of Yamuna. Fourteen soil series are observed in Delhi. Majority of the area is covered by fine to coarse loamy soils with different levels of moisture-retention capacity. Areas under these soils have been converted to urban use. Good-to-moderate quantity soil is being lost to non-agricultural uses. The Aravalli hill range is covered with forests called the Ridges.

The Delhi series consists of very deep, somewhat excessively drained soils. They formed in wind modified material weathered from granitic rock sources. Delhi soils are on floodplains, alluvial fans and terraces. Slopes are 0 to 15 percent. Delhi soils have short undulating slopes of 0 to 15 percent and lack stratification. The mean annual soil temperature at a depth of 20 inches is 15.55 to 18.88°C and the soil temperature usually is not below 8.33°C at any time. The average January soil temperature is about 50 degrees F and the average July temperature is 23.88 to 29.44°C The soil between depths of about 12 to 35 inches is continuously dry from late April or May until late October or early December and is continuously moist in some or all parts all the rest of the year. Very coarse sand is 0 to 5 percent and combined coarse and very coarse sand is 35 percent or less. The soils are somewhat excessively drained; negligible to slow runoff; rapid permeability that are being used for growing grapes, peaches, truck crops, alfalfa and for homesites. Principal native plants are buckwheat and a few shrubs and trees. Typical vegetation is annual grasses and forbs. The soils are mostly light with subordinate amount of medium texture soils. The light texture soils are represented by sandy, loamy, sand and sandy loam; whereas medium texture soils are represented by loam silty loam. The soils that occur in all the blocks in Delhi are generally suitable for irrigating moderately salt resistant crops such as wheat, barley and mustard. The soil texture is predominantly loamy sand in the study area.

(1) Selection of Sampling Locations

Ten soil sampling locations were identified based on the local geological formation and the agricultural practices. The sampling locations are shown in Figure 9.2-3 and presented in Table 9.2-17.

(2) Methodology

The soil samples were collected in the post-monsoon season. The samples collected from all the locations were homogeneous representatives of each location. At random 5 sub locations were identified at each location and soil samples were collected from 30, 60 and 90 cm below the surface. It was uniformly mixed before homogenizing the soil samples.

The samples were packed in polythene bags, labeled in the field with location and number and sent to laboratory for analysis.

Table 9.2-17 Soil Sampling Locations

Station Code	Location	Distance / Direction w.r.t the Project Site	Present Land Use
S1	On the bank of River Yamuna	1.7 /NNE	Agricultural land
S2	Near existing Ash disposal area of BTPS	0.75/NNW	Ash disposal area
S3	On the bank of River Yamuna	1.6 /NE	Agricultural land
S4	Near existing Ash disposal area of BTPS	0.8 /SE	Agricultural land- near existing ash disposal area
S5	On the bank of River Yamuna	1.8/W	Agricultural land
S6	Near existing Ash disposal area of BTPS	1.7/NW	Ash disposal area

Source: Draft Environmental Impact Assessment Report for Badarpur CCPP- NTPC

(3) Soil in the Study Area

1) Physical Characteristics

Sand content is slightly higher and ranges from 77.8% to 86.2%, while silt content is moderate and ranges from 6.7 to 13.5 %. Clay content is lower and ranges from 5.1% to 10.6%. Therefore, as per U.S. Bureau of Soil and Chemistry Textural System (Triangular

Classification System), the Soil in the study area can be described as loamy sand. The water holding capacity of the soil varies between 56.5% - 68.9% with average level of 61.9%

2) Chemical Characteristics

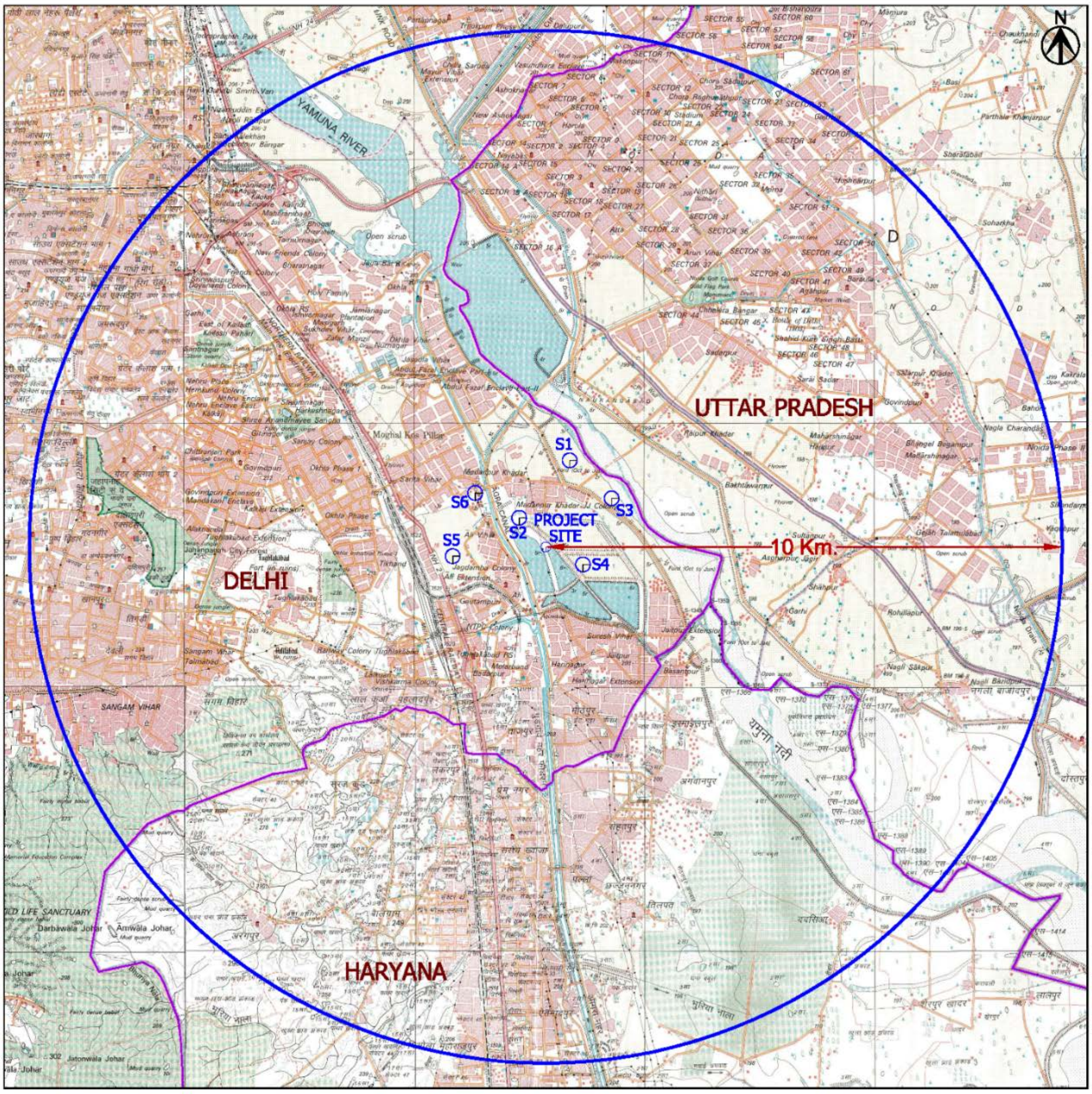
The soil is slightly acidic to alkaline in nature, pH ranging from 6.3 to 7.5. Electrical conductivity (EC) is moderate, varying between 625 to 727 μmhos/cm with an average of 682 μmhos/cm.

Cation Exchange Capacity (CEC) varied between 5.52 – 7.45 meq/100 gm with an average value of 6.70 meq/100 gm.

(4) Fertility Status of Soil

The soil in the study area possesses high organic matter (0.81-0.95%), available phosphorus (13.7-24.2 kg/ha), available nitrogen (511.4-552.1 kg/ha) and available potassium (233.2 to 273.5 kg/ha), which indicate medium fertility or agricultural potential of the Soil.

Thus, soil of the study area is fertile as it falls in the flood plain of riverine system of River Yamuna. The Rating Chart for Available Nutrients in Soil is presented in Table 9.2-27



Source: Survey of India Toposheet, Govt. of India (1:50,000), Base Map No. H43X6

Figure 9.2-3 Soil Sampling Location

Table 9.2-18 Soil Characteristics in the Study Area

Parameters and Units	**Values for Corresponding Sampling Locations**					
	S1	**S2**	**S3**	**S4**	**S5**	**S6**
Physical Characteristics						
Colour	Brown	Brown	Brown	Brown	Brown	Brown
Textural Class	Loamy sand	Loamy sand	Loamy sand	Loamy sand	Loamy sand	Loamy sand
Bulk Density (gm/cc)	1.6	1.2	1.5	1.4	1.5	1.1
Water Holding Capacity (%)	65.8	57.6	65.7	61.3	63.7	56.5
Particle Size Distribution						
Sand (%)	86.2	78.5	84.6	85.1	85.7	77.8

Parameters and Units	Values for Corresponding Sampling Locations					
	S1	S2	S3	S4	S5	S6
Silt (%)	8.3	13.3	10.3	8.7	8.3	12.6
Clay (%)	5.5	8.2	5.1	6.2	6.0	9.6
Chemical Characteristics						
pH	7.4	6.6	7.5	7.3	7.4	6.3
EC (μmhos/cm)	715	625	727	702	710	632
Organic Carbon (%)	0.91	0.81	0.93	0.84	0.95	0.94
CEC (meq/100 gm)	7.12	5.65	7.08	7.32	7.45	5.74
Sodium Absorption Ratio	0.42	0.34	0.45	0.39	0.41	0.32
Nutrients						
Available N (Kg/ha)	535.3	512.2	548.8	522.6	552.1	520.5
Available P (Kg/ha)	22.3	15.8	23.6	21.4	23.7	16.1
Available K (Kg/ha)	264.5	245.6	273.5	247.3	275.5	233.2

Source: Draft Environmental Impact assessment Report for Badarpur CCPP- NTPC

Table 9.2-19 Rating Chart for Available Nutrients in Soil

(in kg/ha)

Parameters	Low	Medium	High
Available Nitrogen (N)	Below 280kg/ha	280-560 kg/ha	Above 560 kg/ha
Available Phosphorus (P)	Below 10 kg/ha	10 – 25 kg/ha	Above 25 kg/ha
Available Potash (K)	Below 110kg/ha	110 – 280 kg/ha	Above 280 kg/ha

Source: Draft Environmental Impact Assessment Report for Badarpur CCPP- NTPC

(5) Infiltration Tests

1) Methodology

With a view to determine the infiltration characteristics of soil mass of the area, Double Ring Infiltrometers were used. The infiltrometer used in the study, consists of two concentric iron-steel made open ended, hollow cylinders of 50cm length each and a centimeter thick wall. The inner diameter of the inner and outer rings is 20 cm and 30 cm respectively. The circular edge of the lower ends of the walls of these rings is relatively sharper as against the blunt end of the upper part. The sharper end of rings help in digging the rings a few centimeters into the soil before infiltrometer test is done. For measurement of infiltration, a device with vernier calliper is attached to the upper part of the inner ring, which helps in measuring the water level falling due to infiltration at specified time interval.

2) Infiltration Parameters and Testing Sites

Using water as a medium of infiltration, tests were carried out at the site at 10 cations within the existing ash disposal area as mentioned in Table 9.2-20. The results of the infiltration test are presented in Table 9.2-21**.**

Table 9.2-20 Infiltration Testing Sites

Sl.No	Testing Sites
1	IR1: ExistingAsh Disposal Area
2	IR2: ExistingAsh Disposal Area
3	IR3: ExistingAsh Disposal Area
4	IR4: ExistingAsh Disposal Area
5	IR5: ExistingAsh Disposal Area
6	IR6: ExistingAsh Disposal Area
7	IR7: ExistingAsh Disposal Area
8	IR8: ExistingAsh Disposal Area
9	IR9: ExistingAsh Disposal Area
10	IR10: ExistingAsh Disposal Area

Source: Draft Environmental Impact Assessment Report for Badarpur CCPP- NTPC

Table 9.2-21 Infiltration Rate on Soils

Sl. No.	Site	Infiltration Rate (fc) in cm/hr (Post-monsoon)
1	IR1: Existing Ash Disposal Area	5.65
2	IR2: Existing Ash Disposal Area	6.12
3	IR3: Existing Ash Disposal Area	5.93
4	IR4: Existing Ash Disposal Area	6.57
5	IR5: Existing Ash Disposal Area	7.02
6	IR6: Existing Ash Disposal Area	6.83
7	IR7: Existing Ash Disposal Area	6.22
8	IR8: Existing Ash Disposal Area	5.78
9	IR9: Existing Ash Disposal Area	6.25
10	IR10: Existing Ash Disposal Area	6.76
	Average	**6.31**

Source: Draft Environmental Impact assessment Report for Badarpur CCPP- NTPC

3) Results

On perusal of Table 2.20, it can be inferred that the ultimate infiltration capacity of soil in and around the existing ash disposal area varies marginally between the various sites ranging between 5.65 and 7.02 cm/hr with average of 6.31 cm/hr.

9.2.10 Water Quality

Yamuna river is the major surface water body in the study area. It is flowing at a distance of 1.6 km from Badarpur TPP from Northwest to Southeast direction. The Agra Canal lies at a distance of 1km in the East from the Badarpur TPS.

Groundwater is the source for domestic requirement and irrigation in rural areas of the region.

The surface and ground water quality characteristics of the study area have been established through monthly monitoring of the following parameters:

a) **Physical Parameters** – pH, conductivity, total suspended solids and dissolved oxygen.

b) **Chemical parameters** – Total dissolved solids, alkalinity, hardness, NO_3, Cl, SO_4, Na, K, Ca, Mg, Silica, oil and grease, PO4, Phenolic compounds BOD and COD.

c) **Heavy metals** – Cd, Cr+6, Cu, Fe, Pb, Zn, Hg, Se and As.

d) Bacteriological characteristics – Total coliform.

(1) Sampling Locations

The surface water quality was monitored at three locations, one in Okhla Barrage-at the emergence point of Agra Canal, one location in Agra Canal at the upstream of intake point and one location in downstream of discharge point in Agra Canal. Ground water quality was monitored at two locations. The surface water quality sampling locations are shown in Figure 9.2-4 and described in Table 9.2-22. The ground water quality sampling locations are shown in Figure 9.2-4 and described in Table 9.2-23.

Table 9.2-22 Surface Water Sampling Locations

Station Code	Source	Location	Distance /Direction w.r.t Project Site
SW1	Okhla Barrage	At the emergence point of Agra Canal	3.0 km/N
SW2	Agra Canal	At the upstream of intake point	1.5 km/SSW
SW3	Agra Canal	Downstream of discharge point	1.9 km/SSW

Source: Draft Environmental Impact Assessment Report for Badarpur CCPP- NTPC

Table 9.2-23 Groundwater Sampling Locations

Station Code	Source	Location	Distance /Direction w.r.t Project Site
GW1	Borewell	Near existing Ash Disposal Area	2.0 km/ESE
GW2	Tubewell	Near existing Ash Disposal Area	1.5 km/NE

Source: Draft Environmental Impact Assessment Report for Badarpur CCPP- NTPC

(2) Methodology of Sampling and Analysis

Water samples were collected on monthly basis during the study period and analyzed or selected physico-chemical and biological parameters. The parameters such as pH, temperature and DO were analyzed at the site itself at the time of collection of sample (with the help of water testing kit developed by CPCB) while for other parameters, samples were preserved and analysed in laboratory. Samples were collected, preserved and analyzed as per Standard Methods for the Examination of Drinking and Waste Water (APHA, AWWA and WPCF) Quality.

(3) Surface Water Quality

The range of values observed for various physico-chemical and micro-biological parameters in the Okhla Barrage, Agra Canal are presented in Table 9.2-24 along with Indian specifications for water quality (IS: 2296-1992). pH of water of Okhla Barrage varied between 7.5 to 8.1 while that of Upstream of Intake Point and Downstream of discharge point in Agra Canal varied between 7.32 to 8.2 which is within the acceptable range of 6.5-8.5. The TDS content varied 236 mg/l to 410 mg/l in all the water samples which is well within permissible limit of 1,500 mg/l. Total suspended solids ranged from 13.1-36 mg/l. Dissolved oxygen levels varied between 3.2 to 5.3 mg/l. BOD levels ranged between 17.6 to 30.6 mg/l. Nitrate and phosphate content were marginal. Iron content ranged between 0.08 to 0.22 mg/l.

Total coliform counts varied in the range of 5700-10450 MPN/100 ml. Oil & Grease and phenolic compounds contents were below detection limit. The degree of hardness varied from 179 to 198 mg/l, which is within permissible limit of 300 mg/l.

1) Conclusions

The results of physico-chemical analysis of water samples of Okhla Barrage and upstream of intake point and in downstream of discharge point of Agra Canal presented in Table 9.2-24 indicates marginal variation in water quality. The water in Okhla Barrage and Agra Canal shows organic pollution reflecting high BOD and low DO content.

(4) Groundwater Quality

The range of values observed for various physico-chemical and microbiological parameters for ground water at two sampling locations are presented in Table 9.2-24. pH varied from 7.1 to 9.2. TDS content varied between 397 to 510 mg/l. Degree of hardness ranged from 114 to 248 mg/l. Calcium varied between 21.5 to 59.3 mg/l which is below the permissible limit of 100 mg/l. BOD varied from 1.0 to 1.8 mg/l and COD varied from 2.0 to 8.0 mg/l.

The chloride level (28 to 390 mg/l) was observed to be higher. The sulphate level varied between 157 to 198 mg/l. The Fluoride content varied from 0.22 to 0.45 mg/l. Oil & Grease and phenolic compounds were below the detectable limit. Most of the heavy metals were absent.

1) Conclusions

The result of physico-chemical analysis of groundwater samples indicates marginal variation in the ground water quality sampling locations. However, most of the parameters are within the permissible limits for Drinking Water Standards and many parameters are within the desirable limits.

Table 9.2-24 Surface Water Quality in the Study Area

Parameters	Unit	SW1 Okhla Barrage	SW2 Agra Canal Upstream of Intake Point	SW3 Downstream of discharge point	IS: 2296 (Class C)
No. of Observations		7	7	7	Tolerance Limit**
Value Observed					
pH	-	7.5 - 8.1	7.40 - 8.2	7.32 - 7.54	6.0 – 9.0
Dissolved Oxygen	mg/l	3.2 - 4.3	3.4 – 5.3	3.5-5.2	4.0
Total Suspended Solids	mg/l	31 - 36	15 - 18	13.1 - 14.3	
Total Dissolved Solids	mg/l	332-394	352-410	236-362	1,500
Conductivity	µmhos/cm	510-612	523-632	415-542	
Turbidity	NTU	2 – 4	3 – 6	2 - 7	
Alkalinity (as $CaCO_3$)	mg/l	64.0 - 65.2	52.2 - 58.3	51.4 - 55.3	200
Hardness (as $CaCO_3$)	mg/l	190 – 198	181 – 188	179 - 196	300
Calcium (as Ca+2)	mg/l	18.8 - 22.1	20.6 - 24.1	18.7 - 24.1	75
Magnesium (as Mg+2)	mg/l	22.7 - 24.3	25.8-27.6	24.7-26.9	30
Sodium (as Na+)	mg/l	3 - 5	3 – 6	2 - 4	
Potassium (as K+)	mg/l	6.2 - 7.2	5.1 - 8.6	4.7 - 7.3	
Nitrate (as NO_3 -)	mg/l	0.11 - 0.15	0.10 - 0.36	0.5 - 0.86	50
Phosphate (as PO_4 -2)	mg/l	<0.02	<0.02	<0.02	
Chloride (as Cl-)	mg/l	54.7 - 64.35	55.21 - 64.12	58.22 - 63.22	600
Sulphate (as SO_{4}-$_2$)	mg/l	24.3 - 31.6	26.5 - 31.3	28.7 - 32.7	400
Fluoride (as F-)	mg/l	0.52 - 0.62	0.34 - 0.76	0.23 - 0.89	1.5

Parameters	Unit	SW1 Okhla Barrage	SW2 Agra Canal Upstream of Intake Point	SW3 Downstream of discharge point	IS: 2296 (Class C)
No. of Observations		**7**	**7**	**7**	**Tolerance Limit****
Value Observed					
Oil & Grease mg/l	<0.01	<0.01	<0.01		
Phenolic Compounds (as C_6H_5OH)	mg/l	<0.005	<0.005	<0.005	0.005
Biochemical Oxygen Demand	mg/l	25.6-30.	2 24.7-30.	6 17.6-25.	4 3.0
Chemical Oxygen Demand	mg/l	15.3 – 56.5	14.2 – 55.9	13.5 – 62.7	
Arsenic (as As)	mg/l	<0.01	<0.01	<0.01	0.2
Mercury (as Hg)	mg/l	<0.001	<0.001	<0.001	
Lead (as Pb)	mg/l	<0.05	<0.05	<0.05	0.1
Cadmium (as Cd)	mg/l	<0.01	<0.01	<0.01	0.01
Hexavalent Chromium (as Cr+6)	mg/l	<0.05	<0.05	<0.05	0.05
Copper (as Cu)	mg/l	<0.05	<0.05	<0.05	1.5
Zinc (as Zn)	mg/l	<1	<1	<1	15
Selenium (as Se)	mg/l	<0.01	<0.01	<0.01	0.05
Total Coliform	MPN/ 100 ml	6100-9806	6352-10450	5700-9402	5,000

** Tolerance limits specified in Indian Specifications for Water Quality (IS:2296 –1992)

Source: Draft Environmental Impact assessment Report for Badarpur CCPP- NTPC

Table 9.2-25 Ground Water Quality in the Study Area

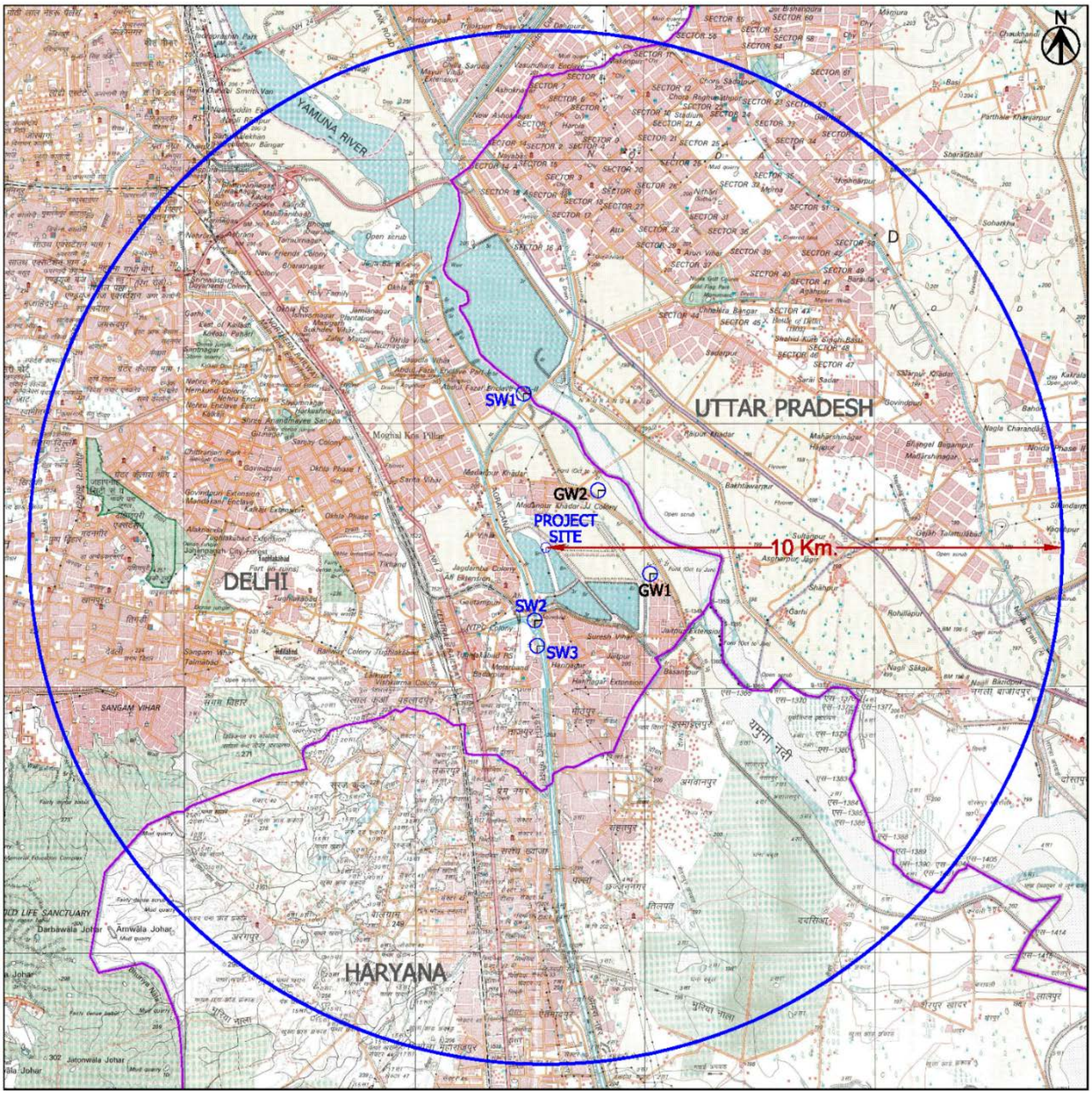
Parameters	Unit	GW-1	GW-2	Drinking Water std (IS:10500)	
No. of Observations		**7**	**7**	**Des** Limit**	**Per* Limit**
Value Observed					
pH	-	7.1 - 8.2	7.5 -9.2	6.5 - 8.5	NR
Total Suspended Solids	mg/l	9 – 12	5 - 9		
Total Dissolved Solids	mg/l	397 – 428	402 - 510	500	2000
Conductivity	µmhos/cm	562-643	567 -798		
Alkalinity (as $CaCO_3$)	mg/l	104 - 275	118 - 310	200	600
Hardness (as CaCO3)	mg/l	114 – 225	128 - 248	300	600
Calcium (as Ca+2)	mg/l	21.5 - 46.3	22.6 - 59.3	75	200
Magnesium (as Mg+2)	mg/l	9.8 - 17.7	12.2 - 19.1	30	100
Sodium (as Na+)	mg/l	51.2 - 145.3	55.6 -151.4		

Parameters	**Unit**	**GW-1**	**GW-2**	**Drinking Water std (IS:10500)**	
No. of Observations		**7**	**7**	**Des** Limit**	**Per* Limit**
Value Observed					
Potassium (as K+)	mg/l	2.2 - 19.6	2.4 - 19.9		
Nitrate (as NO3 -)	mg/l	18 – 28	20 – 25	45	NR
Phosphate (as PO_4 -2)	mg/l	<0.1	<0.1		
Chloride (as Cl-)	mg/l	28 – 327	26 – 390	250	1000
Sulphate (as SO_{4}-$_{2}$)	mg/l	157 – 192	162 - 198	200	400
Fluoride (as F-)	mg/l	0.22 - 0.41	0.23 - 0.45	1.0	1.5
Oil & Grease	mg/l	<0.01	<0.01	0.01	0.03
Arsenic (as As)	mg/l	<0.01	<0.01	0.01	NR
Mercury (as Hg)	mg/l	<0.001	<0.001	0.001	NR
Lead (as Pb)	mg/l	<0.05	<0.05	0.05	NR
Cadmium (as Cd)	mg/l	<0.01	<0.01	0.01	NR
Hexavalent Chromium (as Cr+6)	mg/l	<0.05	<0.05	0.05	NR
Copper (as Cu)	mg/l	<0.05	<0.05	0.05	1.5
Zinc (as Zn)	mg/l	<1	<1	5	15
Selenium (as Se)	mg/l	<0.01	<0.01	0.01	NR
Total Coliform	MPN/ 100 ml	Absent	Absent	10	

** Desirable limit specified in Indian Specifications for Drinking Water (IS: 10500 –1991)

* Permissible limit, in absence of alternate source specified in IS: 10500 – 1991.

Source: Draft Environmental Impact assessment Report for Badarpur CCPP- NTPC



Source: Survey of India Toposheet, Govt. of India (1:50,000), Base Map No. H43X6

Figure 9.2-4 Water Sampling Location – GW&SW)

9.2.11 Meteorology and Climatology

Delhi has a semi-arid climate with high variation between summer and winter temperatures. Due to Delhi's proximity to the Himalayas, cold waves from the Himalayan region dip temperatures across Delhi. Summers are long, from early April till October, with the monsoon season in between. Extreme temperatures have ranged from −0.6°C (10 January 1935) to 47°C. Winter starts in November and peaks in January. Delhi is notorious for its heavy fog during the winter season. In December, visibility is reduced to near zero disrupting road, air and rail traffic in the city. During the summer season, the city faces extreme power and water shortage when the demand for these utilities is at its peak. Every year, the heat wave in summer claims several lives in Delhi. The city, however, has a pleasant climate from February to April and from August to November.

The average annual rainfall is approximately 1,053 mm, most of which falls during the Monsoons, in July and August. Traditionally, the Monsoons are supposed to touch Delhi by June 29th every year.

(1) Past Records

1) Data Collected

Climatological data for the period 1999-2008 of IMD Station, Safdarjung, Delhi located at a distance of about 15 km from the BTPS has been collected and used to bring out the synoptic features of the area. The climatological data collected from the IMD observatory is presented in Table 9.2-26.

2) Temperature

May is the hottest month of the year with mean daily maximum temperature of 40.9°C. Temperature gradually decreases with the onset of monsoon. With the passage of monsoon, in October, both day and night temperature further lowers gradually. December is the coldest month of the year having daily mean minimum temperature of 60C. The average minimum and maximum temperatures are 16.5°C and 30.7°C respectively. Sometimes, minimum temperature further drops down to as low as 50 to 60C due to cold wave blowing from North India. The abstract of the mean monthly maximum and minimum temperature are provided in the Table 9.2-26.

3) Rainfall

The analysis of the rainfall figures show that the rainfall has shown increasing trend since the year 2004. The year 2004 received 594.4 mm rainfall and the year 2008 received 807.3 mm of rainfall.

4) Relative Humidity

The relative humidity is moderate throughout the year. The maximum Relative Humidity recorded is during the month of August and minimum in the month of May.

5) Atmospheric Pressure

The diurnal variation of atmospheric pressure reveals that the barometric pressure is highest during early morning and gradually decreases as the earth's surface starts warming up through absorption of solar radiation to reach a minimum at or immediately after sunset. This diurnal variation has been observed to be true, irrespective of the season. As regards monthly variation, it has been observed that barometric pressure is lowest in the month of July (974.7 mb-830 IST and 971.7 mb- 1730 IST) and highest in December (992.7 mb- 0830 IST and 990.2 mb at 1730 IST).

6) Wind Direction and Speed

Wind directions vary with season. In the summers, the predominant wind directions are from the west in the morning and either west or northwest in the evening. In the monsoons, the predominant wind directions are from the west in the morning and from east (in July and August) or north-west (in June and September) in the evenings. During the post monsoon season, west and calm winds predominate in the mornings while in the evenings, northwest winds are most frequent. In the winter mornings, northwest and west winds dominate, while in the evenings, northwest and north winds are frequent. Analysis of wind records during 1999 – 2008 show that the winds are generally light to moderate in this area with annual mean wind speed of 9.5 km/h. The strongest winds are observed during the months of May – June i.e. Summer Season and the weakest during October – November.

(2) On–Site Meteorology

In order to corroborate and supplement the long-term meteorological data collected from IMD Station Safdarjung and to generate site-specific data, an Automatic Weather Station (WM 250) of M/s Envirotech Instrument Pvt. Ltd. make was earlier installed at the project site at Badarpur Thermal Power Station. In this report the onsite meteorological data generated from May 2010 to November 2010 has been incorporated and analyzed. Monthly variation in on-site meteorological parameters at site has been given in Table 9.2-26.

Table 9.2-26 Monthly Variation in Meteorological Parameters

Month	Temperature (°C)		Relative Humidity (%)		Monthly Rainfall (mm)	Mean Wind Speed (km/h)	Atmospheric Pressure (mb)	
	Min	Max	Min	Max			0830 IST	1730 IST
May’10	21.0	42.2	26.0	97.0	7.6	11.6	979	976
Jun’10	22.9	48.5	30.0	96.0	4.6	12.2	976	973
Jul’10	22.4	42.5	42.0	98.0	236.8	6.2	975	972
Aug’10	26.7	33.6	53.0	100.0	455.1	2.2	978	975
Sep’10	23.6	34.8	45.5	99.8	313.8	7.1	981.5	978.2
Oct’10	13.3	35.5	23.0	94.0	22.0	5.8	988.3	983.5
Nov’10	6.8	30.1	27.0	98.0	13.4	0.85	992	987
Average	**19.5**	**38.2**	**35.2**	**97.5**		**5.74**	**981.4**	**977.8**
Total					**1,053.3**			

Source: Draft Environmental Impact assessment Report for Badarpur CCPP- NTPC

1) **Wind Speed and Direction**

Windrose diagram for the study period have been prepared based on hourly reading of wind speed and direction and shown in Figure 9.6-6.

2) **Temperature**

Minimum temperature was recorded as 6.8°C in the month of November 2010 while the maximum temperature observed was 48.5°C in the month of June 2010. The mean minimum and mean maximum temperature recorded at site were 19.5°C and 38.2°C respectively during the study period.

3) **Relative Humidity**

The mean minimum and maximum relative humidity was observed as 35.2% and 97.5% respectively. The maximum relative humidity 100% was recorded in the month of August 2010.

4) **Atmospheric Pressure**

The diurnal variation of atmospheric pressure reveals that the barometric pressure is highest during early morning and gradually decreases as the day progresses. As regards monthly variation, it was observed that the atmospheric pressure was lowest in July 2010 (0830 IST: 975 mb and 1730 IST: 972 mb) and highest in November 2010 (0830 IST: 992.0 mb and 1730 IST: 987.0 mb). The average atmospheric pressure at 0830 IST and 1730 IST were 981.4 mb and 977.8 mb respectively.

5) **Rainfall**

It would be observed from the Table 9.2-26 that during the study period, the total rainfall was recorded as 1,053.3 mm.

6) **Comparison of Site Meteorological Data with Climatological Data**

The frequency and time of collection of data at the site differs from that of IMD, Safdarjung, Delhi. A comparison of site data generated during six months (May’10 – Nov’10) with that of IMD, Safdarjung reveals the following:

- The temperatures show the similar trend in both the cases.
- The rainfall pattern differs in amount of rainfall recorded in both long term meteorological data and on-site data.

9.2.12 Ambient Air Quality

The prime objective of the baseline study with respect to ambient air quality is to establish the present air quality and its conformity to ambient air quality standards.The major part of the study area represents urban environment. The sources of air pollution in the region are emission from vehicular traffic, dust arising from roads and domestic fuel burning.

This section describes the identification of monitoring locations; methodology adopted for monitoring, frequency of monitoring and results of monitoring during the study period of May 2010 to November 2010.

(1) Methodology adopted for the Study and Results

1) Criteria for Selection of Monitoring Locations

The ambient air quality monitoring locations has been established on the basis of the following considerations:

- Meteorological conditions;
- Topography of the area;
- Sensitive locations;
- Representativeness of locations for obtaining baseline environmental status.

Four ambient air quality monitoring locations were selected in view of the above and in accordance with the prescribed Terms of Reference (TOR), taking into consideration the predominant downwind direction, population zone and sensitive receptors and one monitoring location in the upwind direction.

Logistic considerations as easy accessibility, security, availability of reliable power supply *etc.* were also examined while finalizing the locations.

The distance and direction of these locations with respect to the proposed project site are given in Table 9.2-27.

Table 9.2-27 Ambient Air Quality Monitoring Locations

Station Code	Location	Distance /Direction w.r.t the Project Site	Selection Criteria
AAQ1	Jaitpur	2.5 km/SE	Dominant Downwind Direction and in populated zone
AAQ2	Mithapur	3.0 km/S	Secondary downwind direction
AAQ3	Tughlakabad Railway colony	4.0 km/WSW	Upwind direction as Reference location
AAQ4	Lakadpur	5.0 km/SW	Reserved Forest-sensitive and in dominant upwind direction

Source: Draft Environmental Impact assessment Report for Badarpur CCPP- NTPC

2) Frequency and Parameters for Monitoring

Ambient air quality monitoring was earlier carried out with a frequency of two 24 hourly samples per week at four locations. The baseline data of ambient air has been generated for the following parameters:

- Respirable Suspended Particulate Matter (RSPM) PM2.5, PM10;
- Sulphur Dioxide (SO_2);
- Oxides of Nitrogen (NOx);
- Ozone (O_3) – monthly once at each location on 8-hrly basis.

3) Details of the Monitoring Locations

The monitoring locations represent the areas of maximum deposition, reference ambient air quality and locational characteristics.

4) Instrument used for Sampling

APM-550 and RDS of Envirotech Instrument Pvt. Ltd. make were installed for monitoring Respirable Suspended Particulate Matter (RSPM), and gaseous pollutants like SO_2, NOx, and O_3.

5) Sampling and Analytical Technique

The techniques used for ambient air quality monitoring are as under:

Table 9.2-28 Techniques Used For Ambient Air Quality Monitoring

Parameters	Technique	Minimum Detectable Limit (µg/m^3)	Minimum Reportable Value (µg/m^3)
Particulate Matter (size less than 10 µm) or PM10	- Gravimetric	1.0	10.0
Particulate Matter (size less than 2.5 µm) or PM2.5	- Gravimetric	1.0	5.0
Sulphur Dioxide	- Improved West and Gaeke,	0.04	3.0
Oxide of Nitrogen	- Modified Jacob & Hochheiser (No Arsenite)	0.03	9.0

Source: Draft Environmental Impact assessment Report for Badarpur CCPP- NTPC

(a) Sampling and Analytical Technique for Ozone

The monitoring for ozone was carried out by Alkaline Potassium Iodide (AKI) Absorption method which is based on principle of absorption and colorimetric analysis. This method involved collecting samples in an alkaline potassium iodide (AKI) solution and analyzing them by colorimetry after acidifying with sulfamic acid.

6) Presentation of Results

The summarized data for minimum, maximum, average and 98% tile of PM2.5, PM10, SO_2, NOx and O_3 during the study period are presented in Table 9.2-29

7) Observation Based on Monitoring Data

The observations based on the monitoring results presented in Table 9.2-29 are summarized in the subsequent sub-sections.

(a) Particulate Matter (PM2.5)

The statistical analysis of ambient air quality status in the study area revealed that the maximum concentration of PM2.5 as 65 µg/m^3 was observed in the month of Ocober at the monitoring locations Tughlakabad Railway Colony and Jaitpur. The minimum PM2.5 concentration was recorded as 35.0 µg/m^3 in the month of August at Jaitpur. The average concentration of PM2.5 varied from 47.0 to 47.7 µg/m^3 in the study period.

(b) Particulate Matter (PM10)

The maximum concentration of PM10 was observed at Tughlakabad Railway Colony in the month of May as 327 µg/m^3. The lowest PM10 concentration was observed as 56 µg/m^3 at Jaitpur in the month of October. The average concentration varied from 122.6 µg/m^3 to 135.0 µg/m^3 in the study area.

(c) Sulphur Dioxide (SO_2)

The highest concentration was observed as 14.7 µg/m^3 at monitoring location located in the Tughlakabad Railway Colony in the month of June and lowest concentration 8.1 µg/m^3 at Jaitpur village. The average concentration varied from 9.8 µg/m^3 to 10.6 µg/m^3 during the study period.

(d) Oxide of Nitrogen (NOx)

The highest concentration for NOx was observed as 34.9 µg/m^3 at Tughlakabad Railway Colony in the month of October and lowest concentration as 11.5 µg/m^3 at Jaitpur in the month of August. The average concentration varied from 15.7 µg/m^3 to 16.7 µg/m^3 during the study period.

(e) Ozone (O_3)

In the study area the concentration of ozone varied from 9.0 µg/m^3 to 29.0 µg/m^3 and the mean concentration was observed as 18.7 µg/m^3 at all locations which is well within the prescribed standards of NAAQS.

(f) Conclusions

On the basis of results presented in Table 9.2-29 and Figure 9.2-5 it can be concluded that the concentration of pollutants like SPM, RPM, SO_2 and NOx in ambient air in the study area are well within the permissible limit of NAAQS.

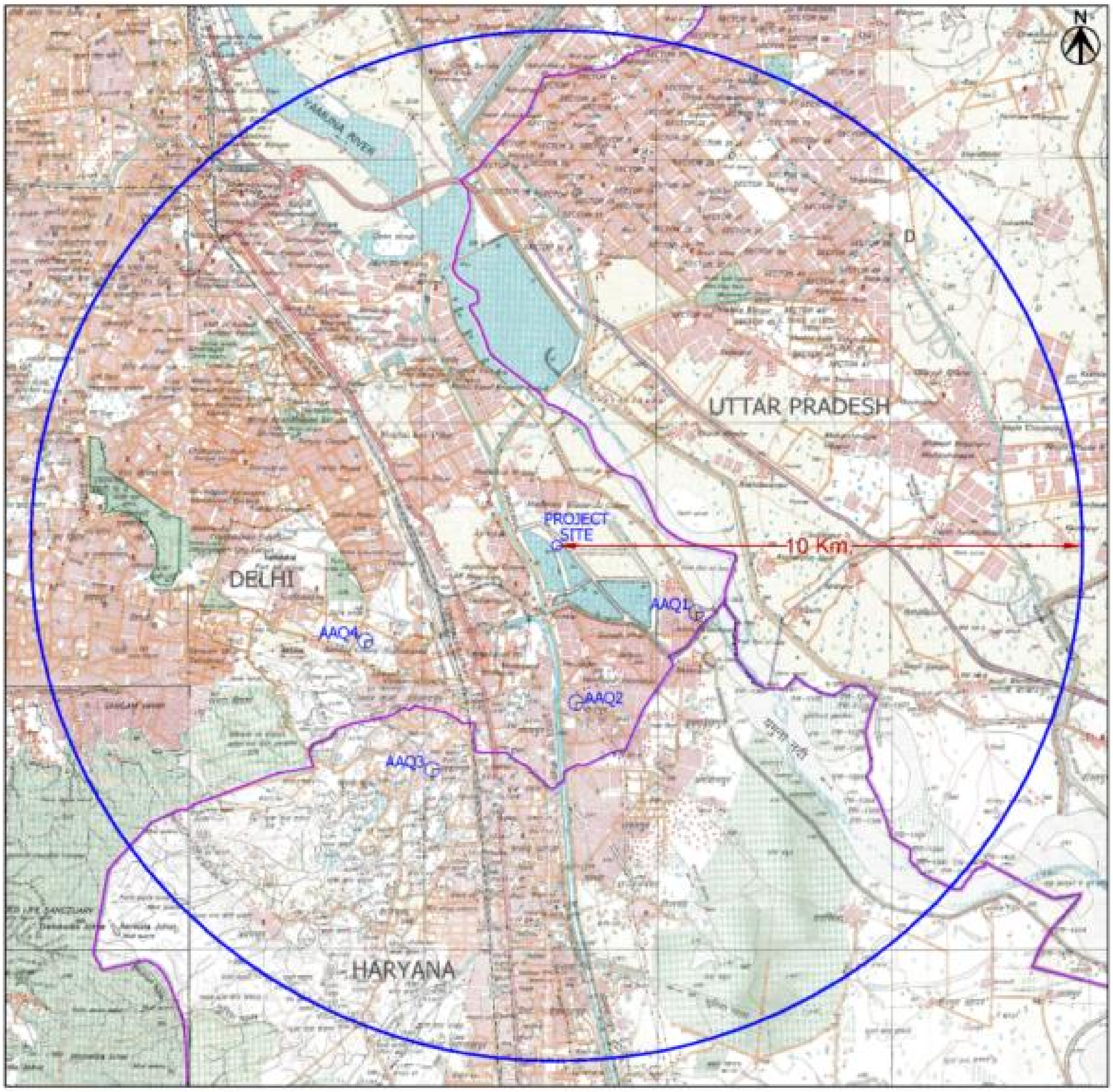
Table 9.2-29 Ambient Air Quality of the Study Area

(Value in µg/m^3)

Sampling Location		PM2.5	PM10	SO_2	NOx	Ozone (O_3)
JAITPUR (AAQ1)	Minimum	35	56	8.1	11.5	9.0
	Maximum	65	305	13.5	32.1	24.0
	Average	47.5	122.6	9.8	15.7	16.6
	98 %tile	62.9	304.8	12.4	24.0	23.8
MITHAPUR (AAQ2)	Minimum	36	61	8.2	12.2	10.0
	Maximum	64	314	13.8	32.4	29.0
	Average	47	135	10.2	16.3	18.8
	98 %tile	62.2	314.2	12.7	25.0	28.5
TUGHLAKABAD RAILWAY COLONY (AAQ3)	Minimum	36	58	8.2	12.4	15.0
	Maximum	65	327	14.7	34.9	26.0
	Average	47.7	127.5	10.4	16.5	20.7
	98 %tile	61.9	324.8	13.5	26.2	25.8
LAKADPUR (AAQ4)	Minimum	36	60	8.4	12.5	10.0
	Maximum	65	324	14.5	34.7	27.0
	Average	47.3	127.6	10.6	16.7	19.0
	98 %tile	61.9	323.4	13.3	25.9	26.9

		PM2.5	PM10	SO_2	NOx	Ozone (O^3)
	Minimum	35	56	8.1	11.5	9.0
	Maximum	65	327	14.7	34.9	29.0
	Average	47.1	128.2	10.3	16.3	18.7
	98 %tile	62.2	316.8	13.0	25.3	26.3

Source: Draft Environmental Impact Assessment Report for Badarpur CCPP- NTPC



Source: Survey of India Toposheet, Govt. of India (1:50,000), Base Map No. H43X6

Figure 9.2-5 Ambient Air Quality Locations

(2) Noise

Ambient noise level measurement was earlier undertaken in the study area in post-monsoon season to assess the existing ambient noise levels in different areas *viz;* Residential, Industrial, Commercial and Silence zones as per the Gazette Notification dated 14.02.2000 of MoEF and The Noise Pollution (Regulation and Control) (Amendment) Rules 2010 on ambient noise standards.

Sound Pressure Level (SPL) was measured by a sound level meter (Integrating Sound Level Meter Cygnet, Model 2031A).

1) Selection of Measurement Locations

The ambient noise level was measured at ten locations in the study area. The sampling locations for the noise measurement were selected keeping in view of the existing industrial, commercial, residential and sensitive areas like hospitals, schools *etc*. The ambient noise monitoring locations and noise level measurement are presented in Table 9.2-30、Table 9.2-31 respectively.

Table 9.2-30 Noise Measurement Locations in the Study Area

Station Code	Location	Distance w.r.t Project Site (km)	Description
N1	Mithapur	3.0	Residential cum, Commercial area
N2	Aligaon	1.7	Residential cum Commercial area
N3	Jaitpur	3.0	Residential cum Commercial area
N4	Lakadpur	5.0	Residential cum Commercial area
N5	Railway Colony	3.8	Residential cum Commercial area
N6	Madanpur Khadar	1.8	Residential cum Commercial area
N7	Lalkuan	4.0	Residential Commercial area
N8	Tughlakabad	5.0	Residential, Commercial & Industrial area
N9	Ismailpur	4.0	Residential cum Commercial area
N10	Tikhand	3.0	Residential cum Commercial area

Source: Draft Environmental Impact Assessment Report for Badarpur CCPP- NTPC

Table 9.2-31 Noise Measurement Locations Inside the Plant

Locations
Turbine Hall
Boiler Feed Pump House
CW Pump House
Cooling Tower
Instrument Air Compressor House
Coal Mill
I D Fan
P A Fan
F D Fan
Diesel Generator

Type of fields for measuring the ambient noise level, can be categorized as free field, near field and far field.

Free Field

The free field is defined as a region where sound wave propagates without obstruction from source to the receiver. In such case, the inverse square law can be applied so that the sound pressure level decreases by 6dB (A) as the distance is doubled.

Near Field

The near field is defined as that region close to the source where the inverse square law does not apply. Usually this region is located within a few wavelengths from the source.

Far Field

The far field is defined as that region which is at a distance of more than 1meter from the source.

2) Parameters Measured

The important parameters measured are Leq, Lday, and Lnight .

Leq**:** Noise analyser have the facility for measurement of Leq, L_{10}, L_{50} and L_{90} directly at 1 octave band.

L_{10} *(Ten Percentile Exceeding Level)* is the level of sound, which exceeds 10% of thetotal time of measurement.

L_{50} *(Fifty Percentile Exceeding Level)* is the level of sound, which exceeds 50% of thetotal time of measurement.

L_{90} *(Ninety Percentile Exceeding Level)* is the level of sound, which exceeds 90% ofthe total time of measurement.

Lday : This represents Leq of daytime. Lday is calculated as Logarithmic average using thehourly Leq's for day time hours from 6.00 A.M to 10.00 P.M

*L*night:This represents Leq of nighttime. Lnight is calculated as Logarithmicaverage using the hourly Leq's for nighttime hours from 10.00 PM to 6.00 A.M.

Method of Measurement

Ambient noise level measurement was carried out continuously for 24-hours outside the plant premises. During each hour, parameters like L_{10}, L_{50}, L_{90} and Leq were directly computed by the instrument. Measurement was carried out at 'A' weighting and in fast response mode.

3) Results and Discussions

(a) Study Area-Outside the Plant

The summary of measured parameters like Leq., Lday, Lnight, L_{10}, L_{50}, L_{90} for all the sampling locations in the respective seasons, are presented in Table 9.2-32 and Figure 9.2-6**.** The overall Leq value varied between 50.7 dB(A) to 60.9 dB(A) in all locations. Day time and night time Leq value varied between 47.4 dB(A) to 58.2 dB(A) and 45.2dB(A) to 51.3 dB(A) respectively. The highest Leq value 60.9 dB(A) was recorded at Railway Colony and the lowest Leq value 50.7 dB(A) was recorded at Madanpur Khadar. The highest Lday 58.2 dB(A) was recorded at Railway Colony and lowest value of Lday 47.4 dB(A) at Madanpur Khadar. The highest value of Lnight 51.3 dB(A) was also recorded at Railway Colony and lowest 45.2 dB(A) at Jaitpur village. It was noted that the noise levels were within the permissible limit of the National Ambient Air Quality Standards with respect to noise both during day time and night time at most of the locations.

(b) Inside the Plant

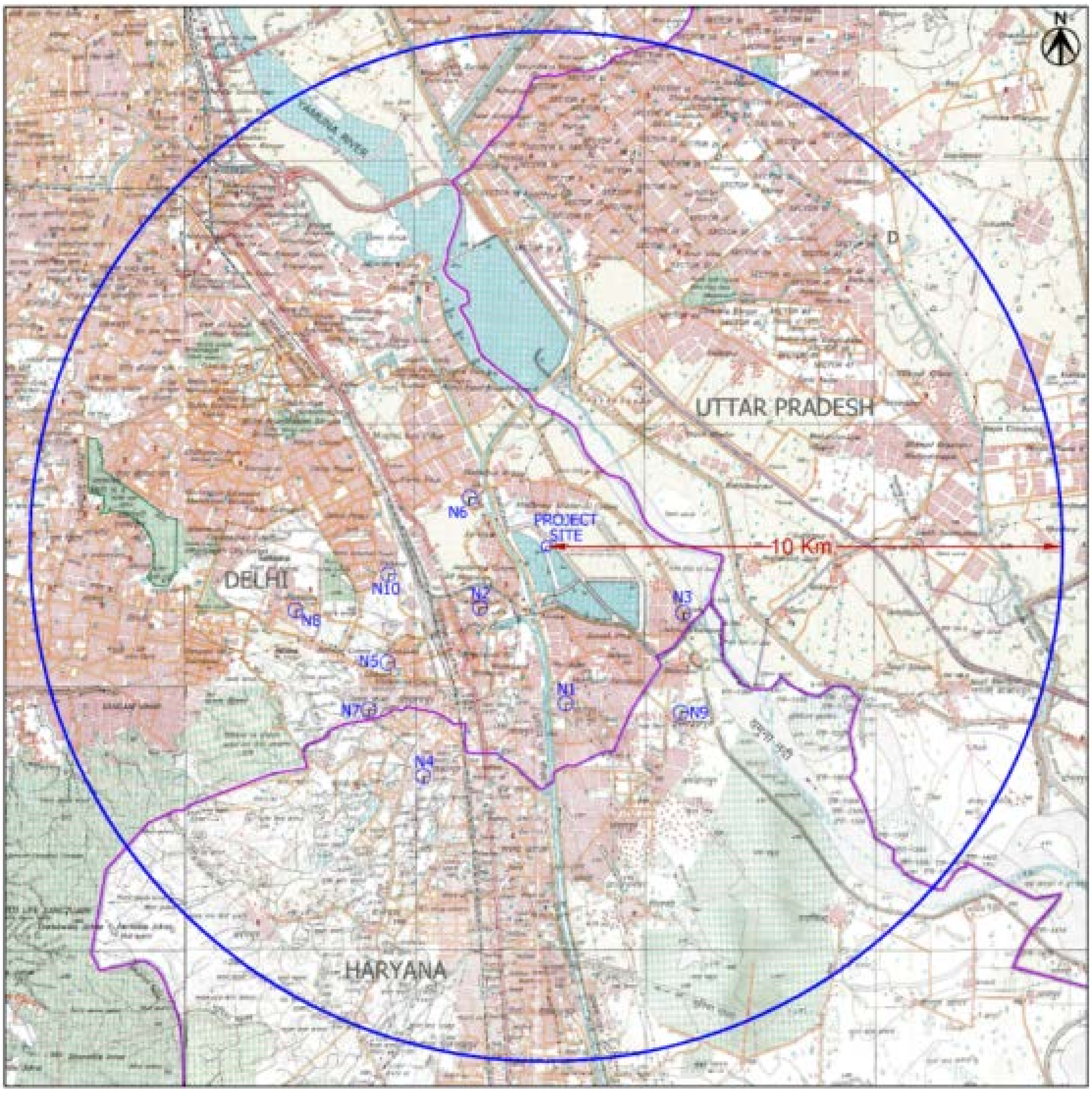
The Leq value varied between 70.3 dB (A) to 87.6 dB (A) at all the locations. Highest Leq was observed in Turbine Hall. The noise levels were within the permissible limit with respect to Damage Risk Criteria for Hearing Loss Occupational Safety and Health Administration (OSHA). The noise levels recorded during monitoring at various sources within the plant premises has been presented in Table 9.2-33**.**

Table 9.2-32 Ambient Noise Levels in the Study Area

Location	**Post-Monsoon**					
	L10	**L50**	**L90**	**Leq**	**Lday**	**Lnight**
	All values in dB(A)					
Mithapur	62.1	59.2	57.9	59.5	56.4	51.2
Aligaon	58.3	55.4	51.6	56.2	52.6	47.5
Jaitpur	54.4	51.2	49.2	51.7	48.7	45.2
Lakadpur	57.3	54.5	51.3	55.1	52.3	48.9
Railway Colony	65.3	59.8	57.2	60.9	58.2	51.3
Madanpur Khadar	53.4	50.3	48.8	50.7	47.4	45.7
Lalkuan	57.9	52.5	49.9	53.6	51.2	48.8
Tughlakabad	62.3	59.8	56.7	60.3	57.8	50.6
Ismailpur	56.3	53.2	49.9	53.9	49.9	46.7
Tikhand	54.3	50.6	46.8	51.6	48.6	45.8

Table 9.2-33 Ambient Noise Levels inside the Plant

Locations	Unit-I	Unit-II	Unit-III	Unit-IV	Unit-V
	All values in dB(A)				
Turbine Hall	84.4	85.2	86.4	86.2	87.6
Boiler Feed Pump House	80.2	81.3	82.1	83.5	84.2
CW Pump House	84.1	83.6	85.2	84.4	85.2
Cooling Tower	70.3	73.2	72.6	81.5	82.7
Instrument Air Compressor House	70.7	71.5	72.1	71.8	72.7
Coal Mill	85.2	86.1	84.8	86.6	87.3
I D Fan	71.6	72.5	73.5	74.5	75.4
P A Fan	80.5	81.1	82.2	81.4	82.3
F D Fan	83.2	82.4	84.1	84.6	85.1
Diesel Generator	80.1	79.6	80.8	81.8	82.4



Source: Survey of India Toposheet, Govt. of India (1:50,000), Base Map No. H43X6

Figure 9.2-6 Noise monitoring locations

(3) Terrestrial Ecology

Natural vegetation and terrestrial ecology of study area is well documented. The floristic and faunal description of the study area is based on the information available from Forest Department of Govt. of NCT of Delhi.

As the natural vegetation has been severely impacted the city forests, the Ridge, the protected and reserved forests have surviving pockets with open spaces which are an admixture of indigenous and exotic species.

1) Flora

Vegetation of Delhi is typical Northern Tropical Thorn Forest Type (Champion & Seth 1968). Among trees, species of Acacia such as *A. nilotica*, *A. leucophloea*, *A. catechu*, *A.*

modesta, *Butea monosperma*, *Cassia fistula*, *Salvadora persica*. Good patches of *Anogeissus latifolia* and abundance of *Prosopis juliflora* are string features. The area is covered by roadside plantations, private and public gardens as well as plantations done by the institutions and housing colonies.

The shrubs include Capparis sepiaria, C.decidua, Zizyphus aenoplia, Croton sparsiflorus. Herbaceous flora include Calotropis procera, Withania somnifera, Achyranthes aspera, Tridax spp., Alysicarpus vaginalis, Peristrophe bicalyculata. Main grasses are Cenchrus ciliaris, Aristida spp., Eragrostis poaeioides, Saccharum spontaneum.

(a) Agroecosystem:

The main crops are rice, wheat, millet, maize and sugarcane. Vegetables are grown in small patches. The major agricultural crops are Mustard (*Brassica juncea*), wheat (*Triticum aestivum*), maize (*Zea mays*), rice (*Oryza sativa*), and millets (*Sorghum vulgare*). A number of leguminous crops are grown for crop rotation purpose such as moong (*Phaseolus mungo*), masoor (*Lens culnaris*), Arhar (*Cajanus cajan*), Gram (*Cicer arietinum*), and pea (*Pisum sativum*).

(b) Groves

The presence of groves in the study area has been noticed. These groves are mainly of *Psidium guava, Citrus auvaulium*, *Mangnifera indica*. The trees grown under social forestry mainly consists of *Mangifera indica*, *Terminilia catapa, Citrus auvaulium, Pisidium guava* and other local species of economic importance.

(c) Plantations

Plantations developed by the State Forest Department and industries. include Babul, Neem, Shisham, Jamun, as main species, planted under afforestation programmes and various social forestry schemes .

Vegetation Analysis: A study was earlier conducted on terrestrial ecology. The results are provided in Table 9.2-34.

Table 9.2-34 Sampling Locations for Terrestrial Ecology

Location Code	Location	Distance/Direction w.r.t the project site	Environmental Setting/ Justification for selection of sampling location
TE1	Asola Wildlife Sanctuary	6.5km/SW	Vegetation around Reserve forest
TE2	Near Yamuna River	2.0km/NNE	Agro ecosystem
TE3	Near Yamuna River and discharge point of BTPS	2.4km/ENE	Agro ecosystem

Source: Draft Environmental Impact Assessment Report for Badarpur CCPP- NTPC

Table 9.2-35 Phytosociological Analysis of vegetation at Sampling Locations

Location	Plant species	Frequency	Density	Abundance	IVI
TE1	Acacia Arabica	50	2.0	0.4	52.4
	Acacia catechu	40	1.5	0.3	41.8
	Cynodon dactylon	30	1.0	0.3	31.3
	Acacia catechu	30	1.5	0.5	32
	Dalbergia sissoo	20	1.0	0.5	21.5
	Adhatoda spp.	20	1.6	0.7	22.3
	Capparis decidua	30	2.0	0.6	32.6
	Azadirachta indica	30	3.0	1.0	34
TE2	Madhuca indica	30	3.0	1.2	34.2
	Abutilon indicum	20	1.5	0.7	22.2
	Acacia Arabica	20	1.0	0.5	21.5
	Croton sparsiflorus	30	1.0	0.4	31.4
	Cassia fistula	20	1.5	0.7	22.2
	Dalbergia sissoo	20	1.0	0.6	21.6
	Cynodon dactylon	10	1.0	1.2	12.2
	Parthenium hysterophorus	20	1.0	0.5	21.5

Location	Plant species	Frequency	Density	Abundance	IVI
TE3	Acacia Arabica	20	2.0	1.2	23.2
	Azadirachta indica	20	1.0	0.6	21.6
	Salmalia malbarica	10	1.0	1.0	12
	Bougainvillea spp.	10	1.2	1.0	12.2
	Chenopodium album	20	1.0	0.4	21.4
	Adhatoda spp.	10	1.0	1.0	12
	Croton sparsiflorus	20	2.0	1.2	23.2
	Eucalyptus globulus	30	2.0	0.7	32.7
	Butea monosperma	10	1.0	1.0	12
	Cynodon dactylon	10	2.0	2.0	14
	Nerium odorum	10	1.0	1.0	12
	Tridax procumbens	10	1.2	1.4	12.6
	Cynodon dactylon	20	1.0	1.0	22
	Saccharum spontaneum	10	2.0	1.8	13.8

Source: Draft Environmental Impact assessment Report for Badarpur CCPP- NTPC

2) Fauna

Faunal description is based literature review.

(a) Wildlife

The Asola Wildlife Sanctuary located at a distance of about 6.5 km in south west direction, was established in 1992 with the aim to protect the wildlife in the area between Delhi and Surajkund (Delhi-Haryana border). The sanctuary covers an area of 26 sq. km. Asola is known bird population than for its animals. Some of these are Bee-eaters, Cormorants, Egrets, Grebes, Falcons, Partridges, Quail, Peafowl, Waterhens, Lapwings, Sandpipers, Woodpeckers, Doves, Parakeets, Cuckoos, Owls, Nightjars, Barbets, Swallows, Shrikes, Orioles, Drongos, Mynahs, Flycatchers, Warblers, Babblers, Wagtails, Pipits, Buntings and Muniahs among many others.

Among the other wildlife found are the Nilgai or Blue Bull, Common Mongoose, Small Indian Civet, Small Indian Mongoose, Jungle Cat, Flying Fox, Porcupine, Palm Squirrel, Spiny tailed Lizards, Rufus Tailed Hare and Monitor Lizards. The sanctuary also has two large enclosures for Blackbuck and Chital or Spotted Deer conservation, rehabilitation and breeding programmes.

(4) Aquatic Ecology

Study of aquatic ecology was earlier carried out by selecting three sampling locations- in the Agra Canal, at the emergence point from the Okhla Barrage built across Yamuna River, upstream of Intake point and downstream of discharge point. The results are provided in Table 9.2-36 and Table 9.2-37.

1) Plankton Population

The phytoplanktons are represented by following species dominated by *Anabaena, Eichhornia crassipes, Nostoc, Oscillatoria* at all the sampling locations.

Among the zooplanktons, Rotifera, Copepoda, Cladocera, Ostracoda and Protozoa were observed. The zooplankton species recorded in the post-monsoon season is presented in Table 9.2-36.

Table 9.2-36 Phytoplanktons recorded at Sampling Locations

Name of the species	Name of the species	Name of the species
AE1	AE2	AE3
Achyranthes aspera	*Achyranthes aspera*	*Achyranthes aspera*
Anabaena	*Eichhornia crassipes*	*Chenopodium ambrosioides*
Eichhornia crassipes	*Eragrostis poaeoides*	*Eichhornia crassipes*
Eragrostis poaeoides	*Chenopodium ambrosioides*	*Eragrostis pilosa*
Eragrostis poaeoides	*Eragrostis pilosa*	*Eragrostis poaeoides*
Marsilea quadrifoliata	*Eragrostis poaeoides*	*Lippia nodiflora*
Nostoc	*Lippia nodiflora*	*Marsilea quadrifoliata*
Oscillatoria	*Marsilea quadrifoliata*	*Nymphea stellata*
Phragmites karka	*Nymphea stellata*	*Phragmites karka*
Scirpus maritimus	*Nostoc*	*Polygonum glabrum*
	Oscillatoria	*Rivularia*
	Polygonum glabrum	*Scirpus maritimus*
	Scirpus maritimus	

Source: Draft Environmental Impact assessment Report for Badarpur CCPP- NTPC

Table 9.2-37 Zooplanktons recorded at Sampling Locations

Name of the species	Name of the species	Name of the species
AE1	AE2	AE3
Brachionus bipentata	*Alona*	*Alona*
Brachionus calcyflorus	*Brachionus calcyflorus*	*Bosmina*
Brachionus diversicornis	*Brachionus diversicornis*	*Cyclops spp.*
Brachionus folculus	*Brachionus folculus*	*Daphnia pulex*
Euglena spp.	*Daphnia carinata*	*Daphnia lumholtzi*
Paramecium caudatum		*Microcyclops spp*
Daphnia carinata		
Daphnia pulex		
Daphnia lumholtzi		
Daphnia simili		

Source: Draft Environmental Impact assessment Report for Badarpur CCPP- NTPC

2) Macrophytes

Aquatic macrophytes are the large, predominantly angiospermic inhabiting aquatic ecosystem and are of great importance from the productivity point of view. They play a very important role in providing food to fishes and other aquatic animals, providing shelter to algae and some animals and also play a vital role in cycling of nutrients in the existing water body (Agra Canal at Okhla Barrage).

Aquatic Macrophytes:
Typha angustata
Phragmites maxima
Hydrilla verticillata,
Vallisneria spiralis,
Potamogeton pectinatus, P. crispus,
Najas sp.
Salvinia molesta
Alternanthera philoxeriodes

3) Fish and other Biota

The commercially important fishes available in the area are *Catla catla*, *Labeo rohita, Cirrhinus mrigla* etc. The earlier survey also indicated more than 14 species of fishes observed in the Okhla Barrage of Yamuna River as listed in Table 9.2-38.

Table 9.2-38 Fishes recorded in Yamuna River at Okhla Barrage

Sl. No.	Scientific Name	Common Name
1.	*Labeo rohita*	Rohu
2.	*Gadusia chapra*	Suhiya
3.	*Catla catla*	Bhakur
4.	*Aspidoparia morar*	Chelwa
5.	*Ambypharyngodon*	Dhawai
6.	*Labeo guntea*	Lotani
7.	*Mystus vittatus*	Tengara
8.	*Puntius sarana*	Darhi
9.	*Puntius sophore*	Pothia
10.	*Esomus dandricus*	Derba
11.	*Chanda nama*	Chanda
12.	*Chanda ranga*	Chanda
13.	*Macrognathus aculeatus*	Pateya or gaincha
14.	*Macrognathus punchalus*	Patgaincha

Source: Draft Environmental Impact Assessment Report for Badarpur CCPP- NTPC

9.3 Pollution Reduction & Social Benefits

The replacement of very old and inefficient power plant having configuration of 3 × 95 MW and 2 × 210 MW, with super critical technology based 2 × 660 MW new power plant is expected to have a lot of advantages and benefits. Added to this, with the implementation of latest emission standards there will be positive improvement in the air quality in spite of doubling the power generation capacity. Thus major benefits are expected to be:

- Improvement in ambient air quality
- Efficient use of water
- Improved availability of quality power to the communities
- Improved quality of life
- Better and increased livelihood opportunities due to availability of more power

In addition, there will be several intangible benefits in terms of community health, education, and recreational facilities and so on.

9.4 Anticipated Impacts & Mitigation

When the new 2 × 660 MW power plant comes into operation after dismantling and disposal of old plant, adverse environmental impacts in terms of air quality, water quality, noise etc. are not expected. However, during demolition of the old plant and construction of new plant there could be adverse impacts, such as,

- Generation of dust and smoke
- Generation of high decibel noise
- Pollution of water
- Disturbance and annoyance of the local population
- Inconvenience to the commuters

It is therefore suggested that a through and detailed planning would have to be done and proper mitigation measures should be adopted to ensure that the adverse impacts are kept within manageable tolerance.

9.5 Presence / Absence of Anticipated Problems

The project envisages dismantling of existing 3 × 95 MW and 2 × 210 MW Coal base power plants and putting in its place new 2 × 660 MW Coal based power plant. No additional land will be required by the project. Keeping this in view the notification/ guidelines applicable to the project have already been discussed in the previous sections.

No additional environmental and social issues are anticipated at this project in time.

In order to conduct a proper EIA study of this project, in accordance with the requirement of MoEF&CC, a standard terms of reference (ToR) is placed in the **Annexure - III**. It is, however, understood that as per the prevailing procedure, a proper ToR will be issued by the MoEF&CC based on the submission of application and Form-1 to the Ministry.

9.6 Atmospheric Dispersion Simulation

A dispersion simulation modeling study has been carried out for the Proposed 2 × 660 MW power plant considering chimney height of 150 meters.

(1) Introduction

Prediction of impacts on air environment has been carried out employing mathematical model based on a steady state Gaussian plume dispersion model designed for multiple point sources for short term. Prediction of ground level concentrations (GLC's) due to proposed project has been made by Industrial Source Complex, Short Term (ISCST3) as per CPCB guidelines. ISCST3 is US-EPA approved model to predict the air quality. The model uses urban dispersion and regulatory defaults options as per guidelines on air quality models (PROBES/70/1997-1998). The model assumes receptors on flat terrain. The ISC short term area source model is based on a numerical integration over the area in the upwind and cross wind directions of Gaussian plume formula. This can be applied to the Point, Area, Line or Volume sources simultaneously and their resultant incremental concentration of the pollutant can be predicted.

- Model Options Used For Computations

The options used for short-term computations are:

The plume rise is estimated by Briggs formulae, but the final rise is always limited to that of the mixing layer;

Stack tip down-wash is not considered;

Buoyancy Induced Dispersion is used to describe the increase in plume dispersion during the ascension phase;

Calms processing routine is used by default;

Flat terrain is used for computations;

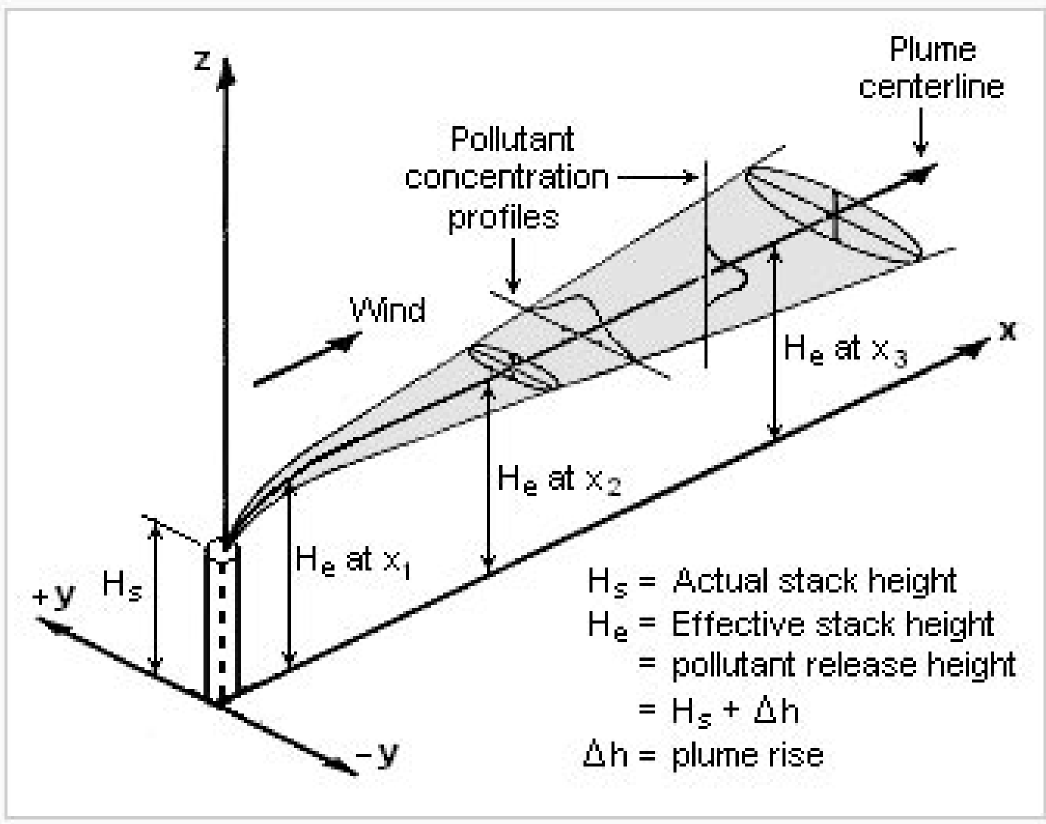
It is assumed that the pollutants do not undergo any physico-chemical transformation and that there is no pollutant removal by dry deposition;

Washout by rain is not considered;

Cartesian co-ordinate system has been used for computations; and
The model computations have been done for 10 km with 1,000-m interval.

- Gaussian Plume Model

Ground Level Concentrationχ, from a point source at any receptor is given by (USEPA ISCST3, 1995).



Visualization of a buoyant Gaussian air pollutant dispersion plume

Source: ISCST3 Tech Guide www.weblakes.com

Figure 9.6-1 Gaussian Air Pollutant Dispersion Plume

$$\chi(x,y,z,H) = \frac{Q}{2\pi\sigma_y\sigma_z\bar{u}}\left[\left\{\exp\left(\frac{-y^2}{2\sigma_y^2}\right)\right\}\left\{\exp\left(\frac{-(z-H)^2}{2\sigma_z^2}\right)+\exp\left(\frac{-(z+H)^2}{2\sigma_z^2}\right)\right\}\right]$$

where,

Q = source strength

Z = receptor height above the ground

H = effective stack height (Plume rise + Physical stack height)

u = wind speed at stack level

σ_y & σ_z = dispersion parameters

1) Air Pollution from Thermal Power Plant

The emission of air pollutants from a power plant would depend upon various factors, viz. fuel quality, process technology, design capacity, air pollution prevention/control measures, operation and maintenance of power generating units and air pollution control equipment associated with the individual power modules. The severity of impacts on air environment from any power project is also governed by terrain features around the project site and the prevailing micrometeorological conditions in the project area. Generally, in a power project besides the main units like boilers, turbines are also associated with several onsite and offsite facilities, viz. fuel storage, backup generator sets etc., which also contribute to air pollution in the form of fugitive emissions, but not significantly. The emissions through stacks (point sources) at power plant are very important for evaluation of impacts of pollutants emission from thermal power plan on surrounding environment.

2) Methodology

This section describes the detailed methodology used in the project. It includes site visit to collect the secondary information, historical data collection (primary and secondary), generation of wind rose diagram to see the dominating wind direction in winter and summer seasons. The ISCST3 model run for point sources (all stacks). For the purpose of predicting the impact of the proposed air emissions on the existing ground levels of air pollutants, an area of 10 km X 10 km from the stacks has been considered. 24 hourly average maximum GLCs have been predicted at grid receptor locations. In the present study, maximum GLCs are predicted for 24hrs average considering complex terrain features of the study area.

3) Model Input Parameters

- Control input: parameters
- Dispersion Option: Regulatory default,
- Pollutant averaging: 24 hours, Pollutant Type: SO_2, NOx and PM_{10},
- Dispersion coefficient : Urban
- Terrain Type: Complex

Source locations (X, Y): stack 1 (X =726964.44, Y= 3156442.26); Stack 2 (X = 727271.41, Y=3156377.85)

- *Receptor location*: Maximum GLC has been predicted at grid receptor locations of 441 with 1 km x 1km distance between each receptor location (Figure 9.6-2, Figure 9.6-3)

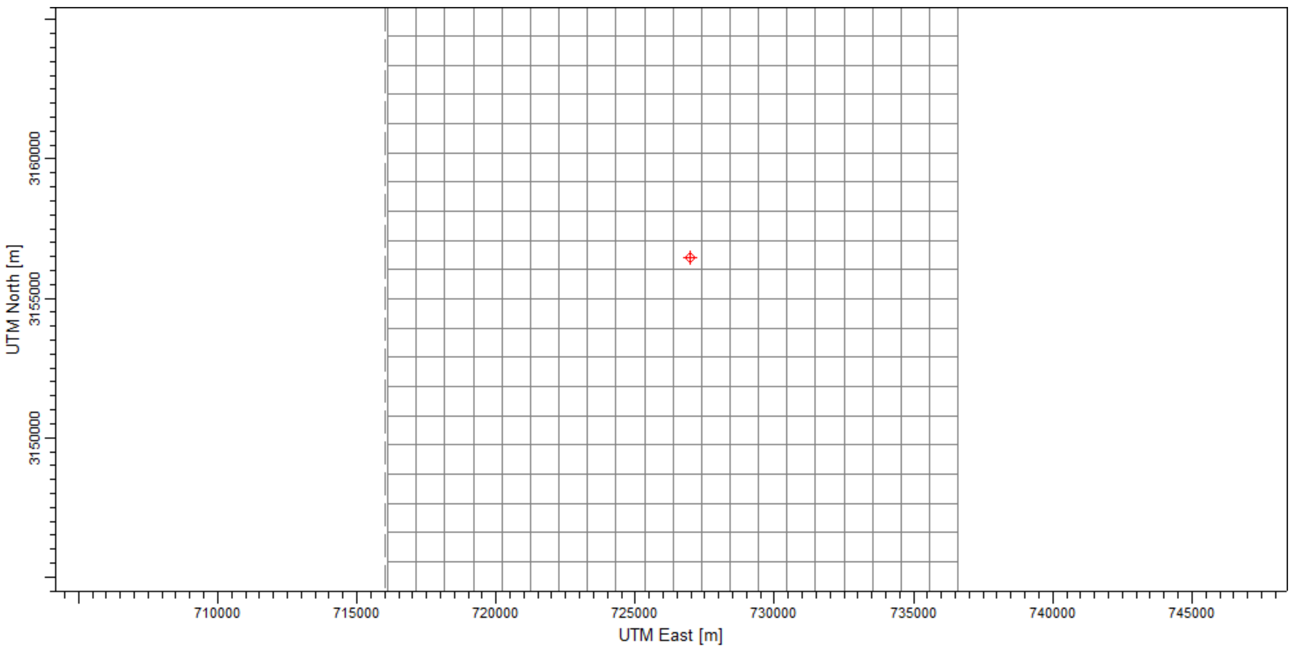


Figure 9.6-2 ISCST3 screen shots showing stack location and receptor grid.

Figure 9.6-3 Stacks location used in modelling (cross checked on goggle earth)

4) Meteorological File:

The micro meteorological data for study area have been collected from the ambient monitoring station operated by Delhi Pollution Control Committee (DPCC) which is located near to the study site. Wind speed, direction, relative humidity, ambient temperature, cloud cover and solar radiation parameters are collected for this study. The mixing height data for Delhi city for winter and summer seasons have been taken from "*Atlas of Hourly Mixing Height and Assimilative capacity of atmosphere in India*" by

Attri et al., 2008. The RAMMET (pre-processor for meteorological data) has been run to produce specific format file which is used as input in ISCST3 model. Figure 9.6-4 ~ Figure 9.6-6 describe the windrose diagram of meteorological parameters for winter and summer and annual data, respectively. Most of the wind speed was found to be in range of 0.5 to 2.1 m/s, however during summer, most of the time, wind speed are found to be 2.1 to 3.6 m/s. It indicates that meteorological conditions more favorable for dispersion of air pollutant during summer season. The dominant wind direction in winter season were West and West North West, however, during summer season, it is West and South West.

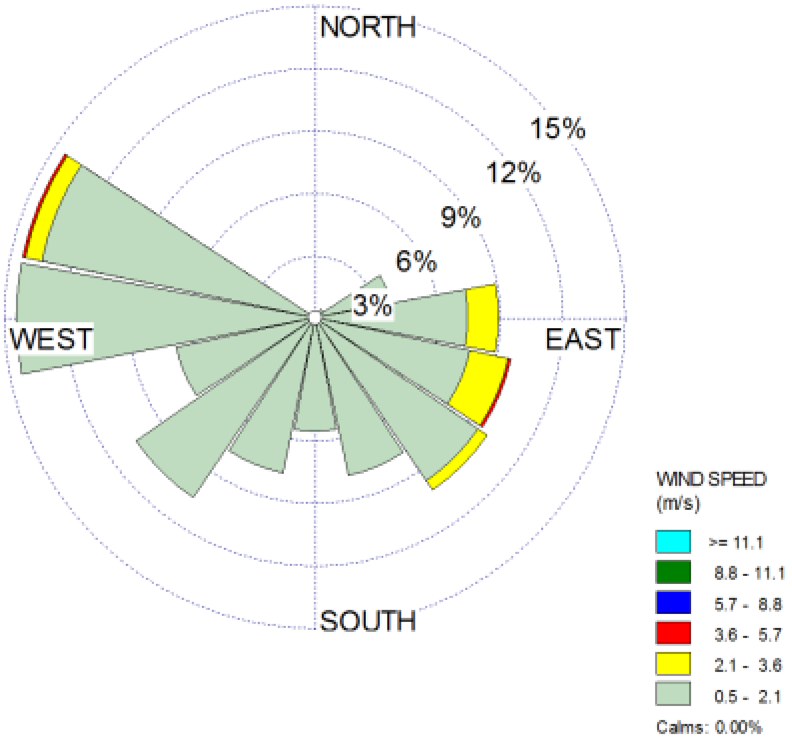


Figure 9.6-4 Windrose for Winter Season

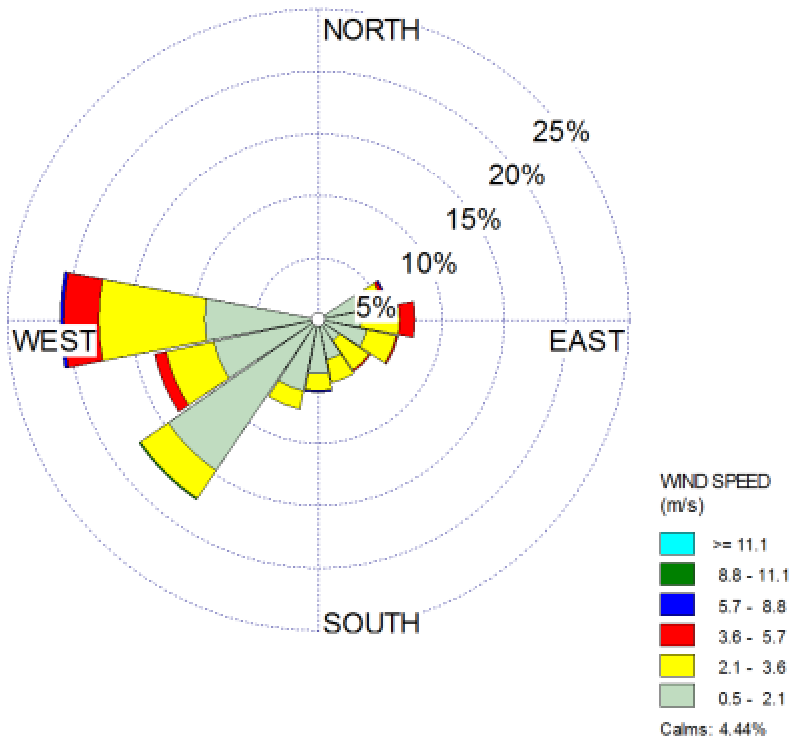


Figure 9.6-5 Windrose for Summer Season

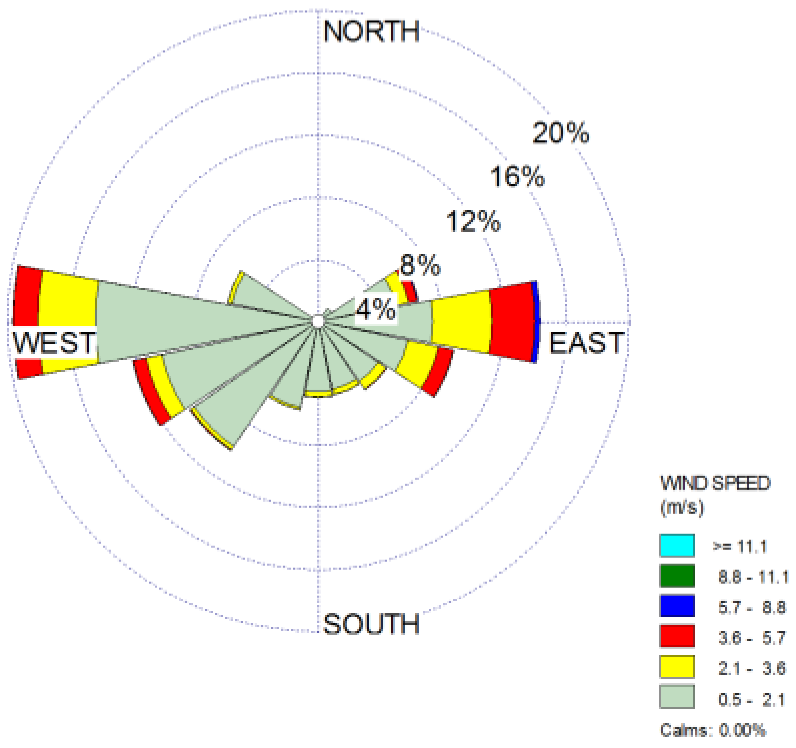


Figure 9.6-6 Windrose for Annual meteorological Data

5) Emission details of Stacks

Table 9.6-1 Input Data

Parameter	Unit	Value	Reference
Capacity	MW	2 × 660	-
Number of Stacks	Nos.	1 (Twin flue)	-
Physical Stack height	m	150	-
Internal diameter of stack at top	m	6	-
Exit velocity of the flue gas	m/s	23.4	-
Temperature of the flue gas	$^{\circ}C$	90	-
Mass flow rate	Nm^3/hr	2260000	-
Emission limit for NOx	mg/Nm^3	100	-
Emission limit for SO_2	mg/Nm^3	100	-
Emission limit for PM_{10}	mg/Nm^3	30	-

MoEFCC (2015). Emission limits for SO_2, NOx and PM from Thermal Power Plants, Ministry of Environment, Forest and Climate Change, New Delhi, GoI., S.O. 3305 (E).

6) Results

ISCST3 model has setup and run for short-term (24 hour average) simulations to estimate concentrations at the receptors to obtain an optimum description of variations in concentrations over the site in 10 km radius covering 16 directions (Figure 9.6-7 ~ Figure 9.6-24). The 24 hour average predicted pollutants concentrations have been added to the baseline concentrations and found the incremental value.

(a) NOx

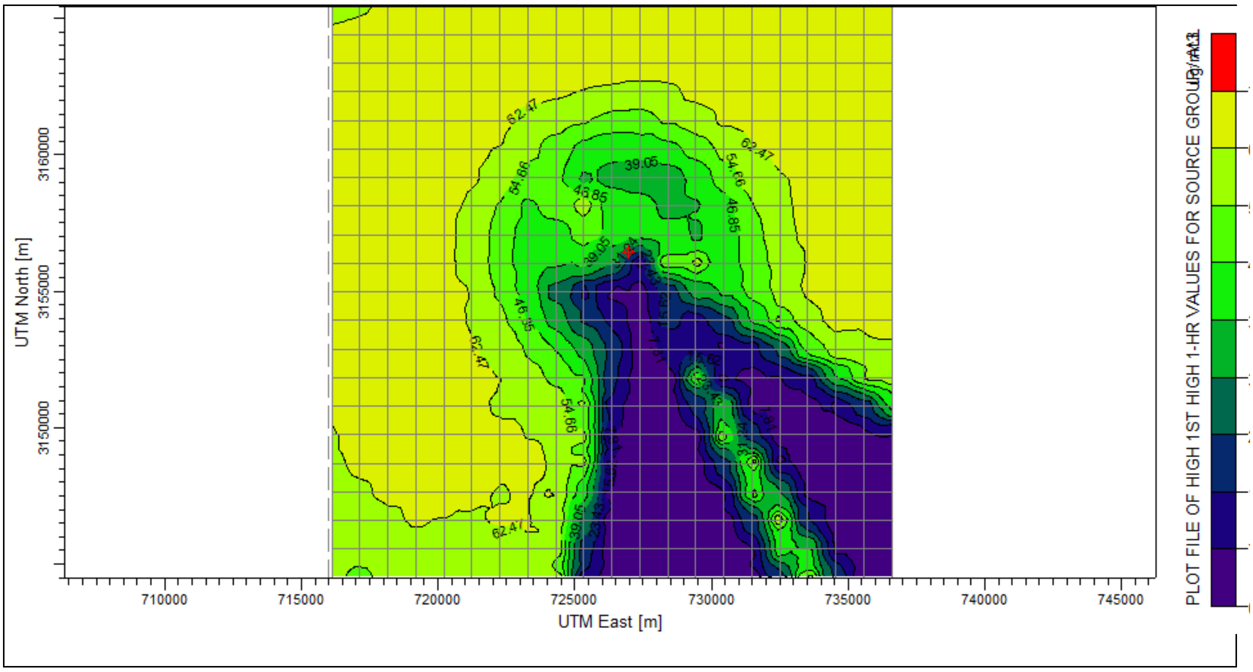


Figure 9.6-7 Predicted Ground Level Concentration of NOx (hourly average)

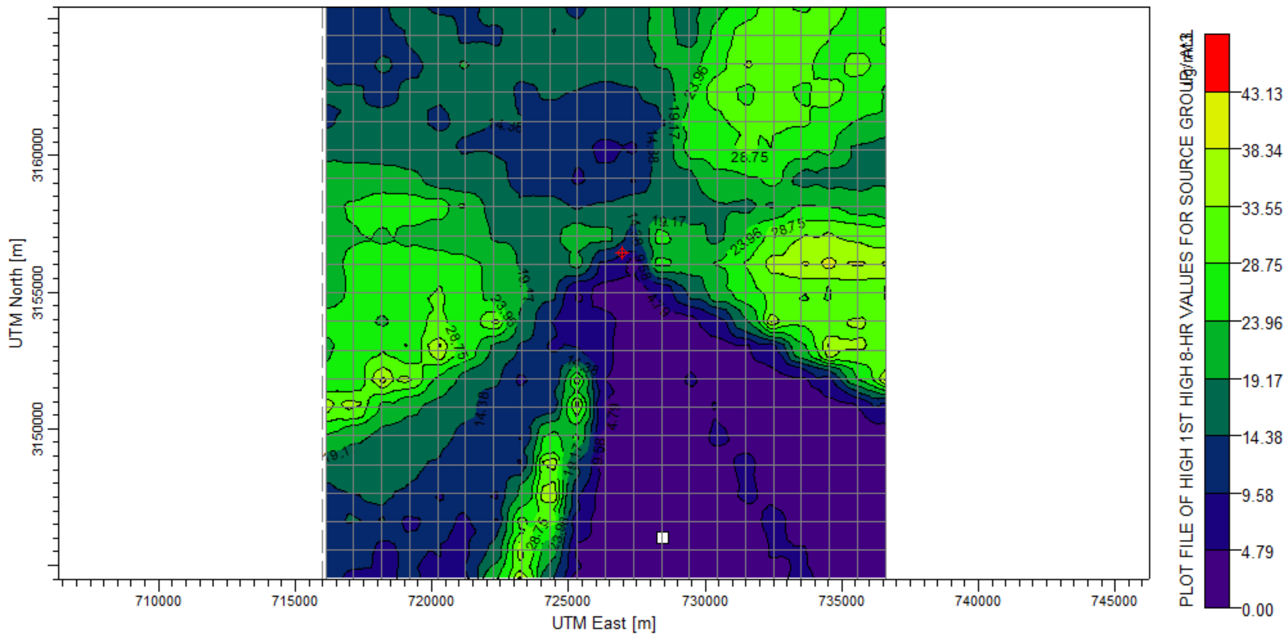


Figure 9.6-8 Predicted Ground Level Concentration of NOx (8 hour average)

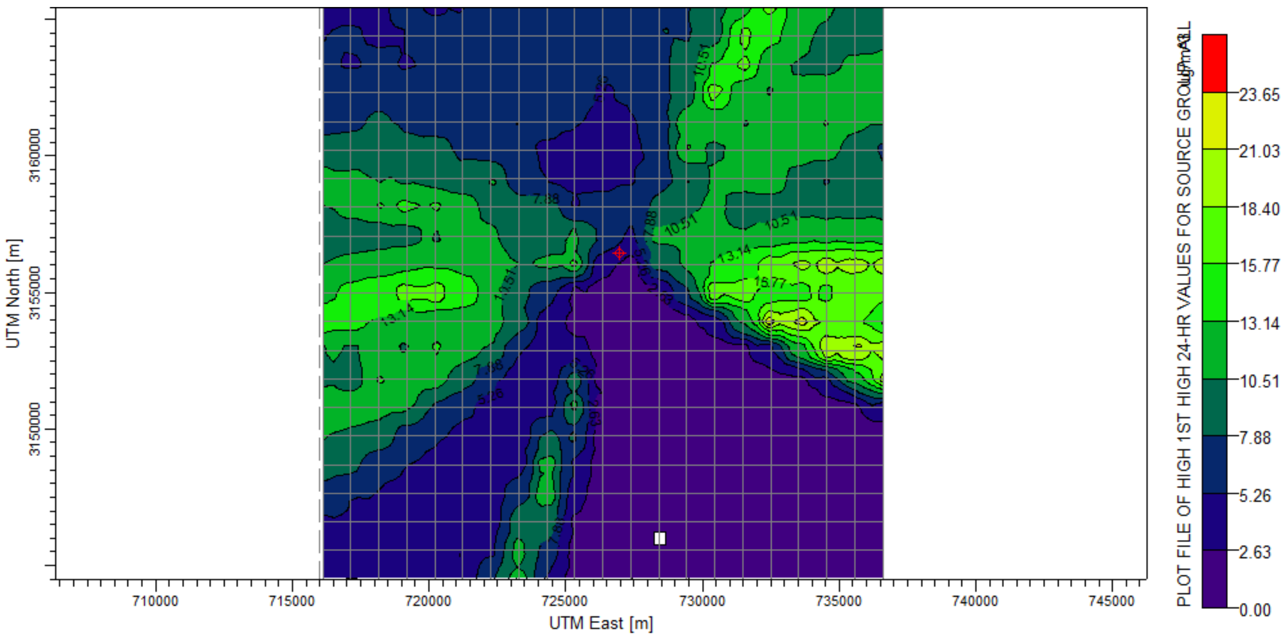


Figure 9.6-9 Predicted Ground Level Concentration of NOx (24 hour average)

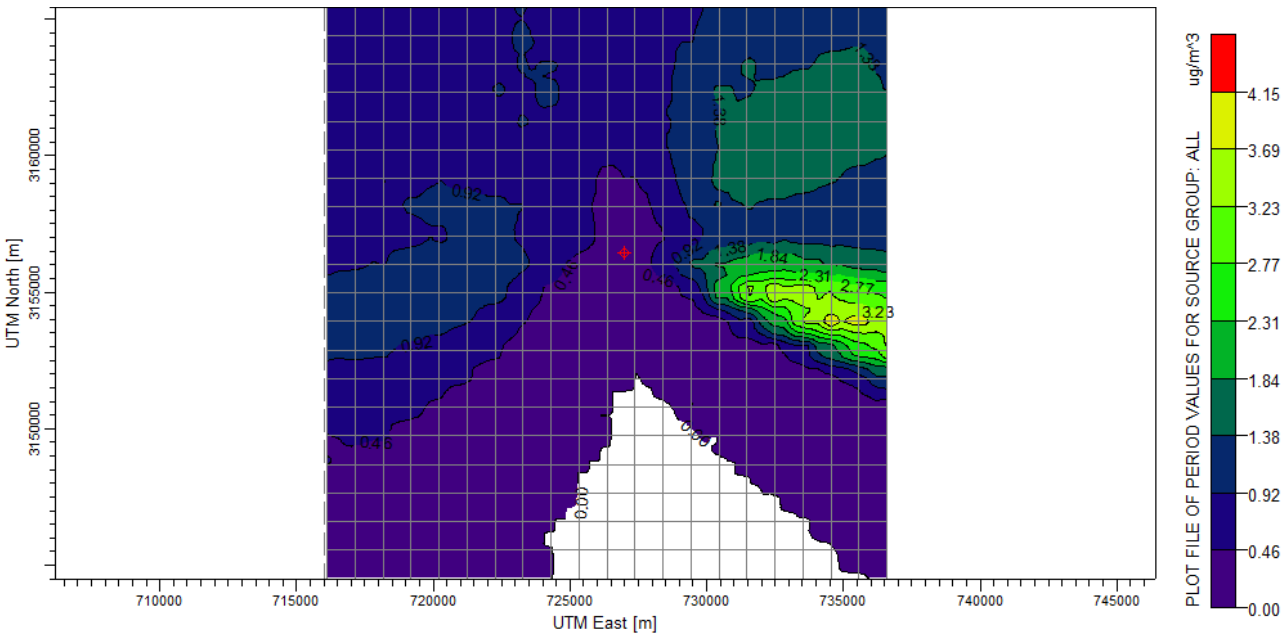


Figure 9.6-10 Predicted Ground Level Concentration of NOx concentration during Winter Season (Average)

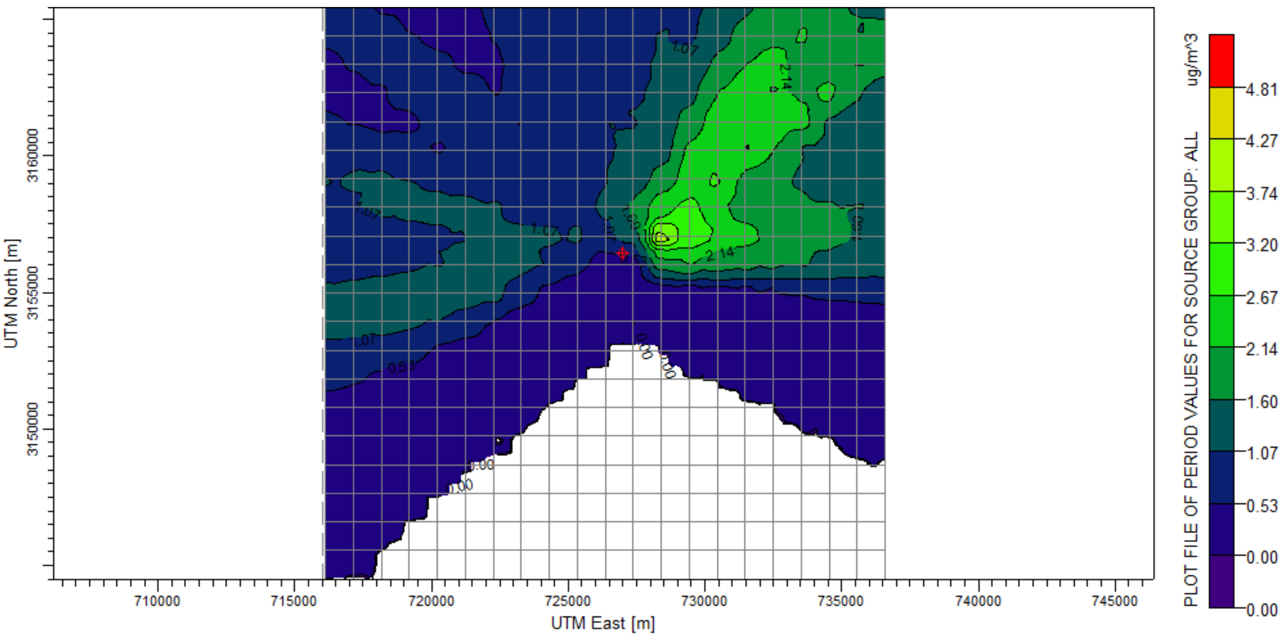


Figure 9.6-11 Predicted Ground Level Concentration of NOx Concentration during Summer Season (Average)

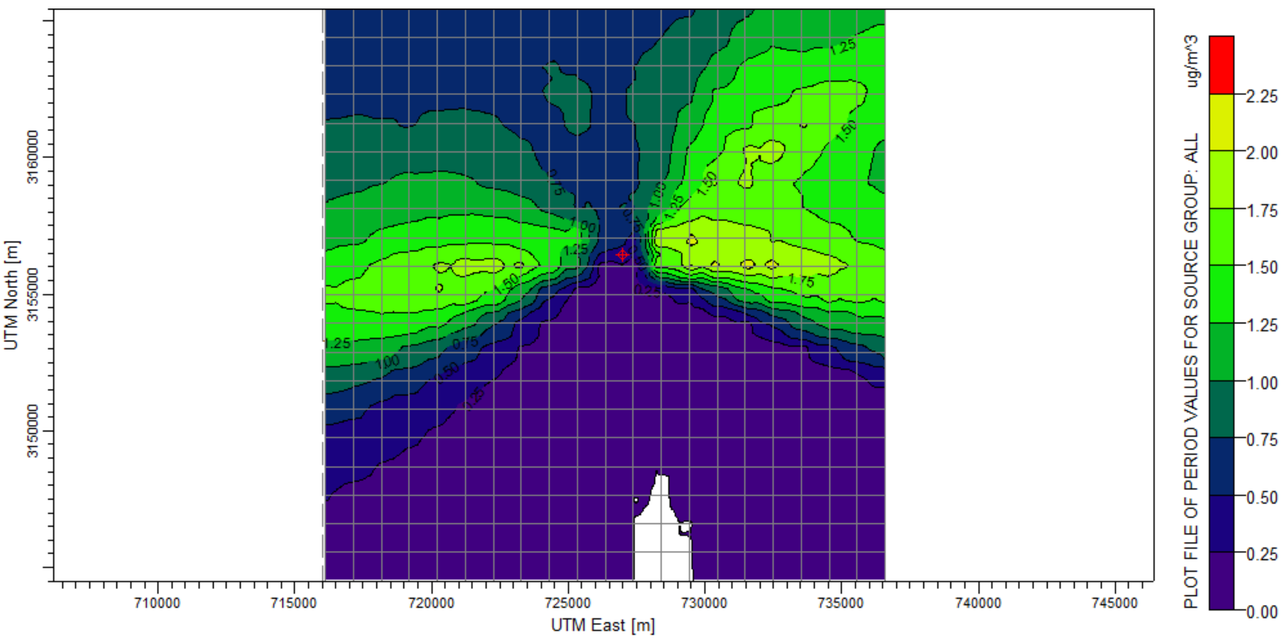


Figure 9.6-12 Predicted Maximum Ground Level Concentration of NOx Concentration (Annual average)

(b) PM10

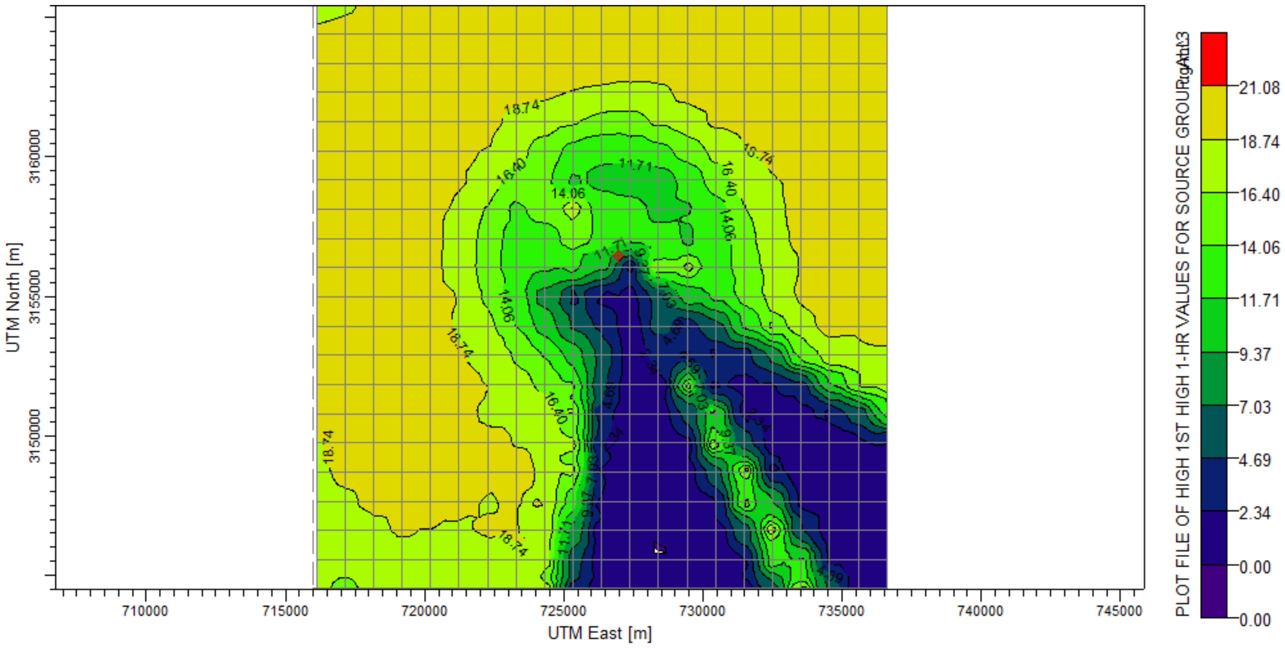


Figure 9.6-13 Predicted Ground Level Concentration of PM10 (hourly average)

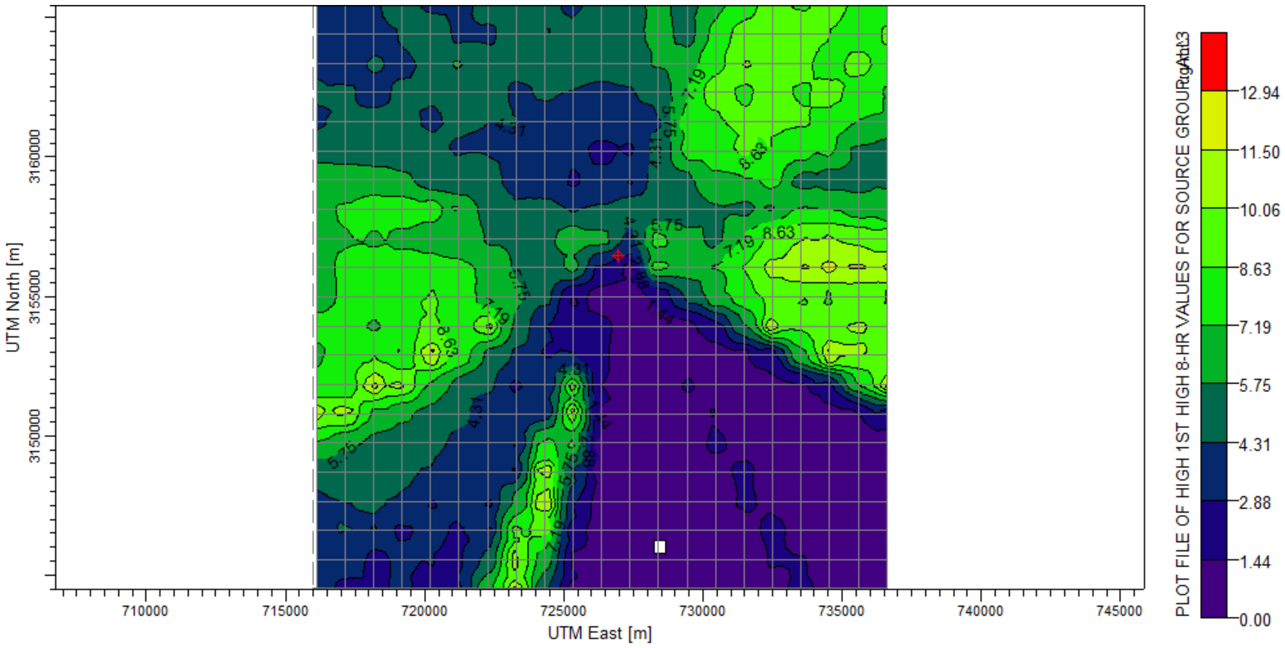


Figure 9.6-14 Predicted Ground Level Concentration of PM10 (8 hour average)

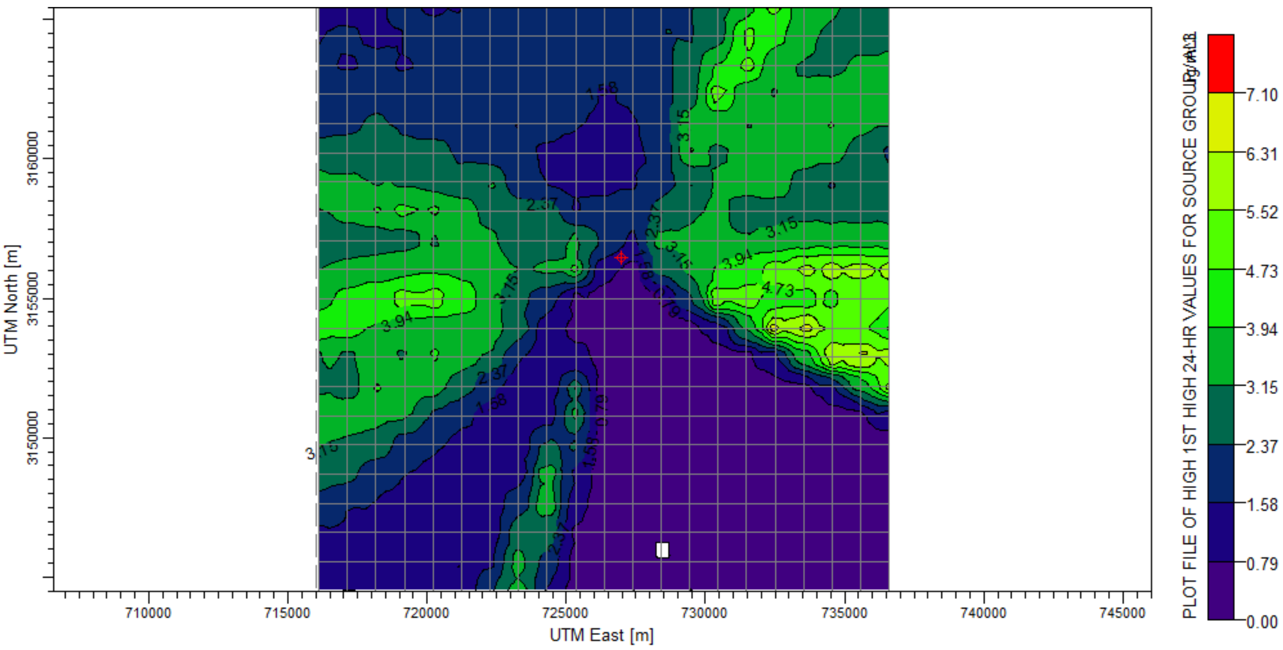


Figure 9.6-15 Predicted Ground Level Concentration of PM10 (24 hour average)

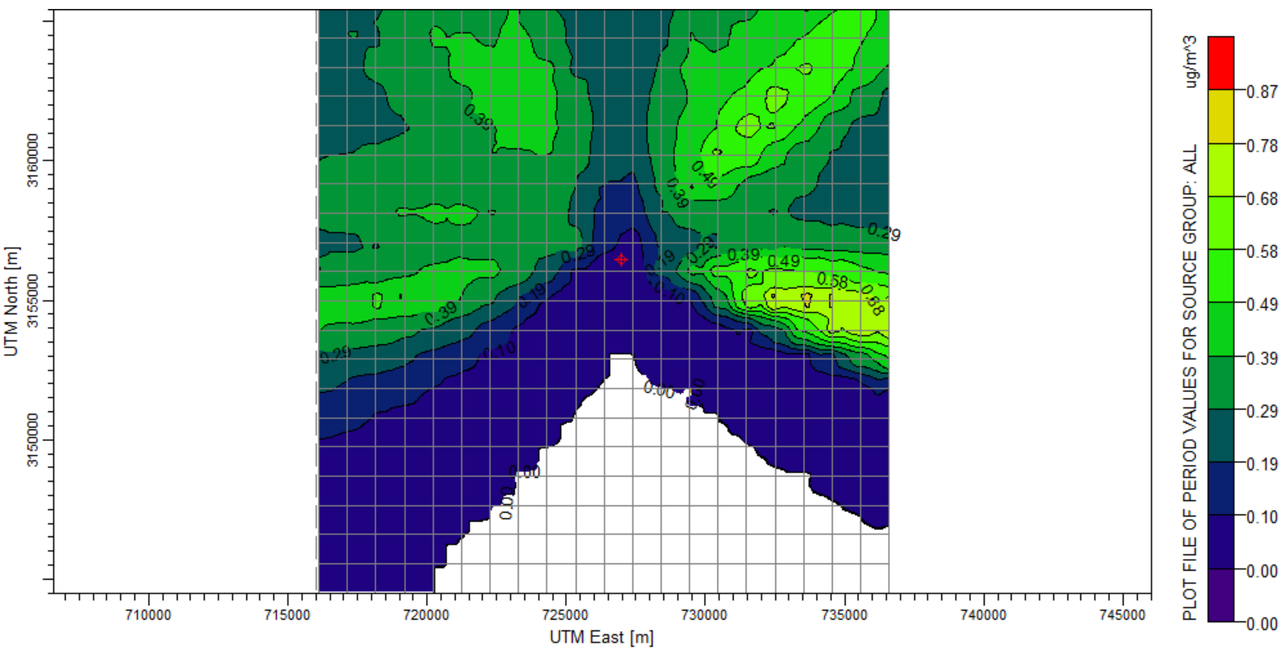


Figure 9.6-16 Predicted Ground Level Concentration of PM10 Concentration during Winter Season (Average)

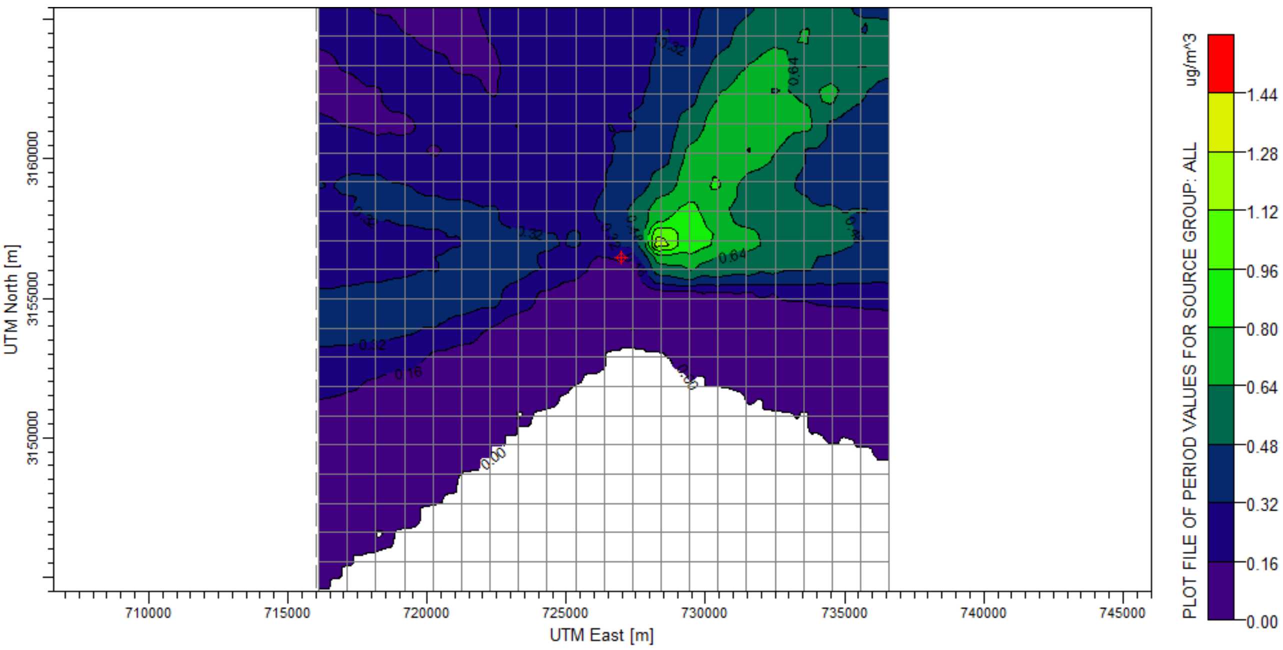


Figure 9.6-17 Predicted Ground Level Concentration of PM10 Concentration during Summer Season (Average)

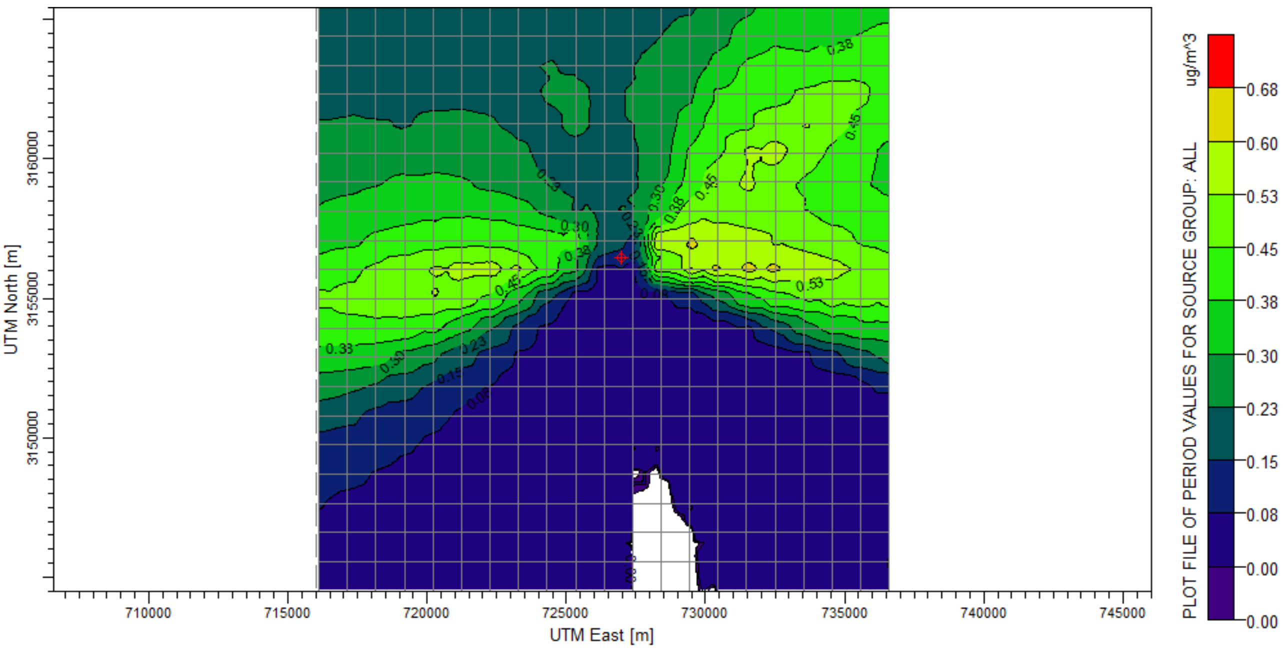


Figure 9.6-18 Predicted Ground Level Concentration of PM10 Concentration (Annual average)

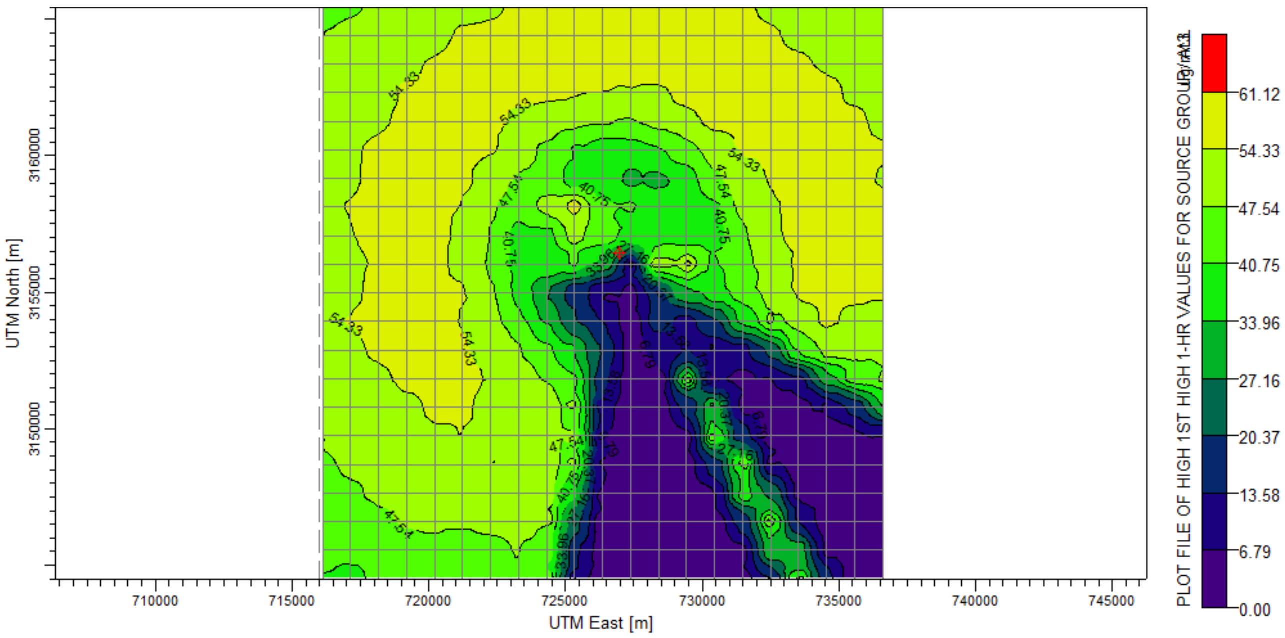


Figure 9.6-19 Predicted Ground Level Concentration of SO_2 (hourly average)

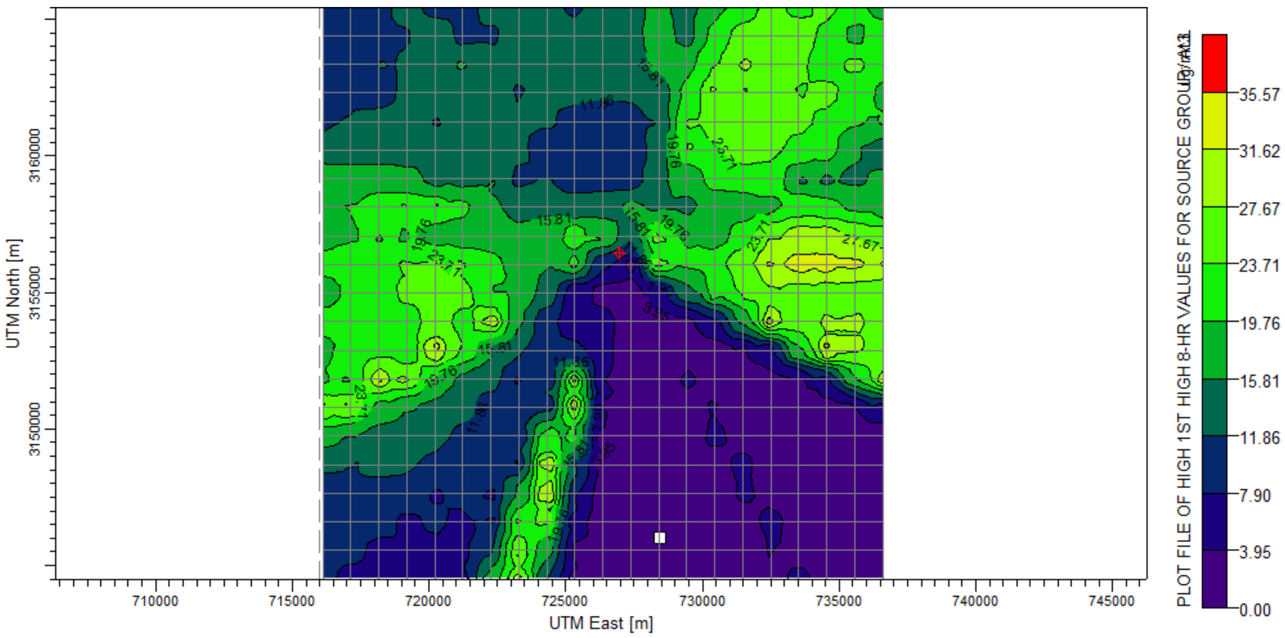


Figure 9.6-20 Predicted Ground Level Concentration of SO_2 (8 hour average)

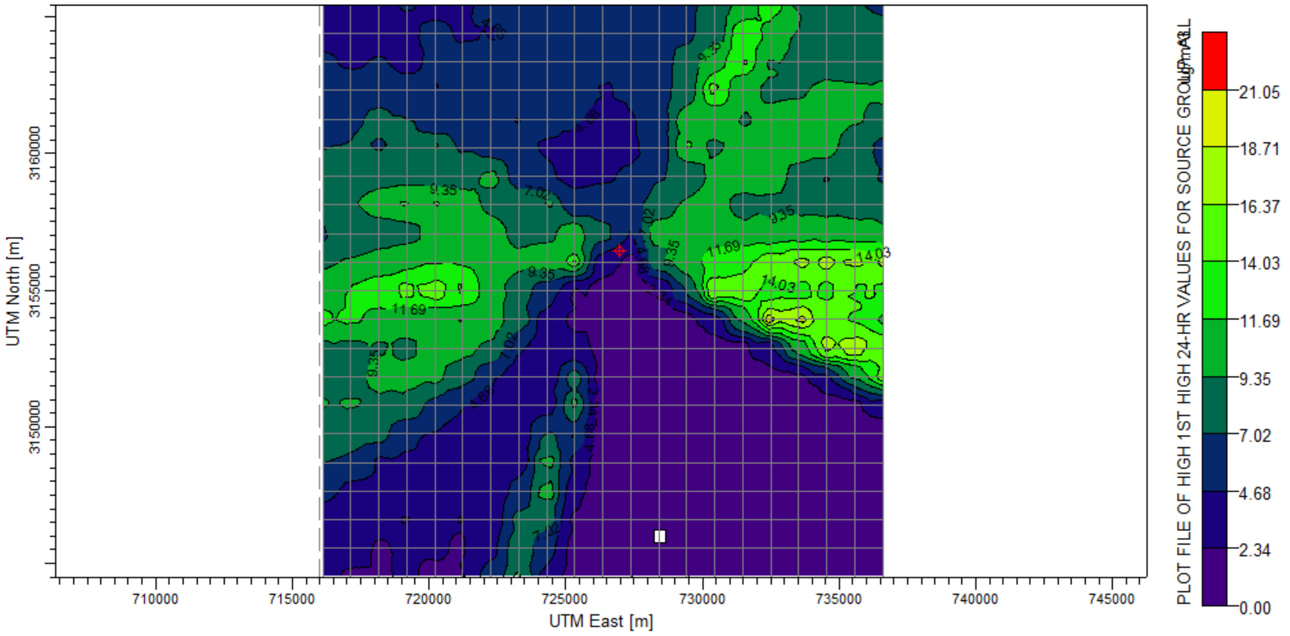


Figure 9.6-21 Predicted Ground Level Concentration of SO_2 (24 hour average)

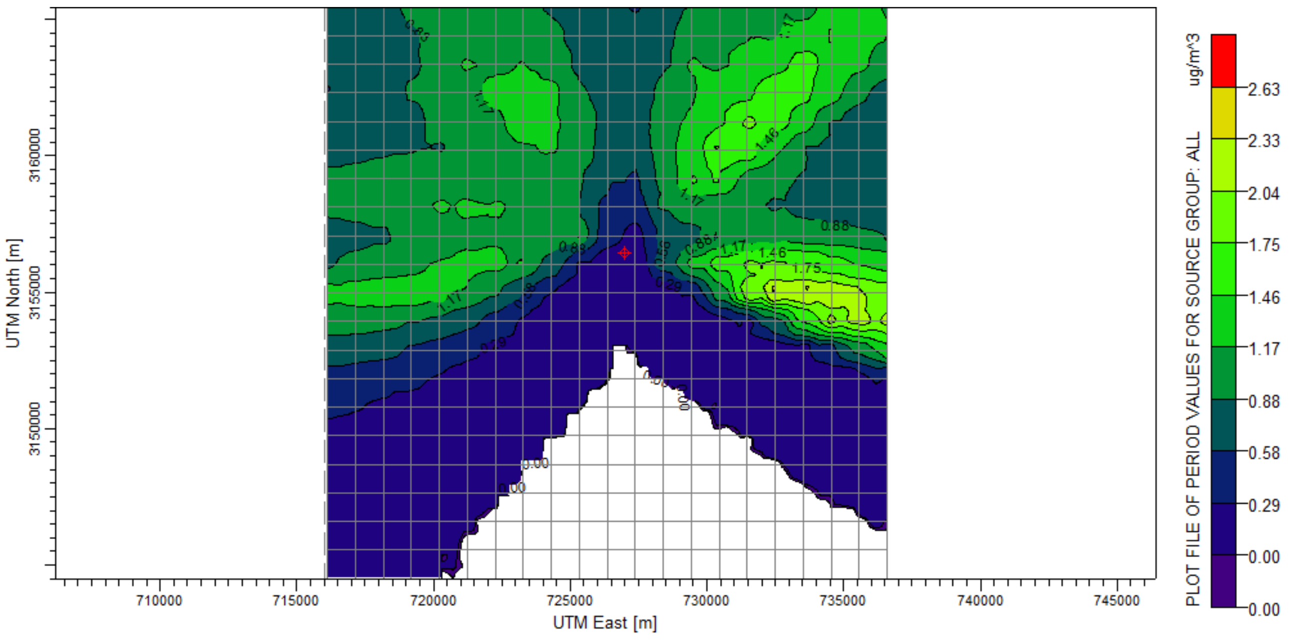


Figure 9.6-22 Predicted Ground Level Concentration of SO_2 Concentration during Winter Season (Average)

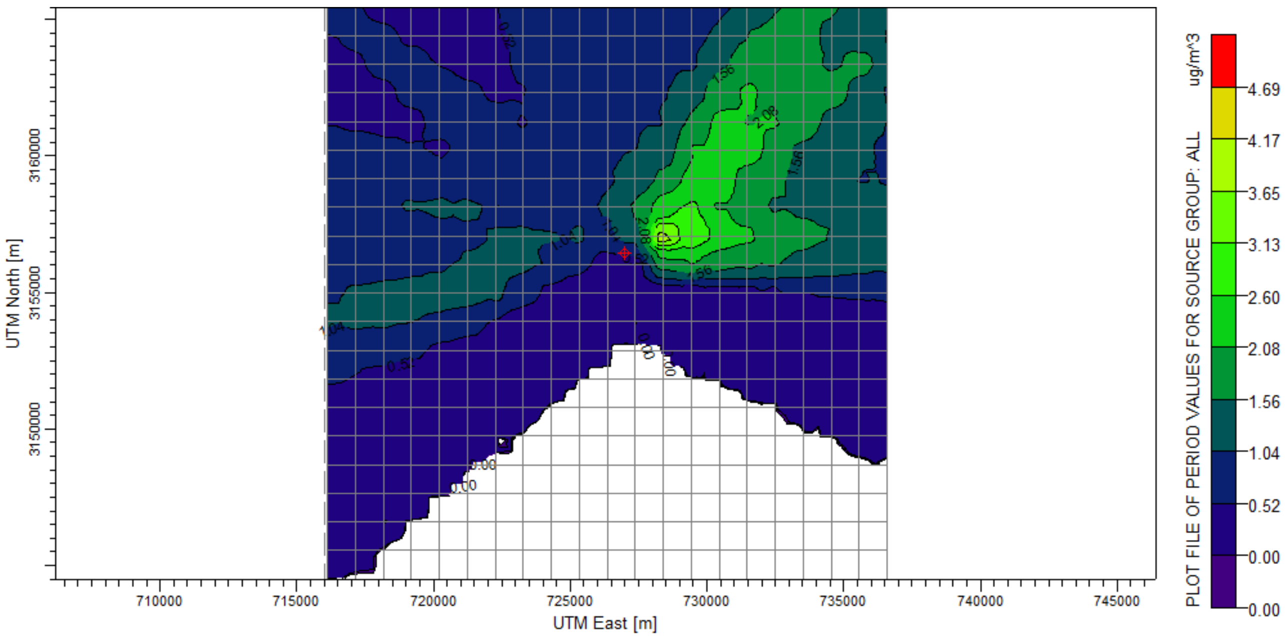


Figure 9.6-23 Predicted Ground Level Concentration of SO_2 Concentration during Summer Season (Average)

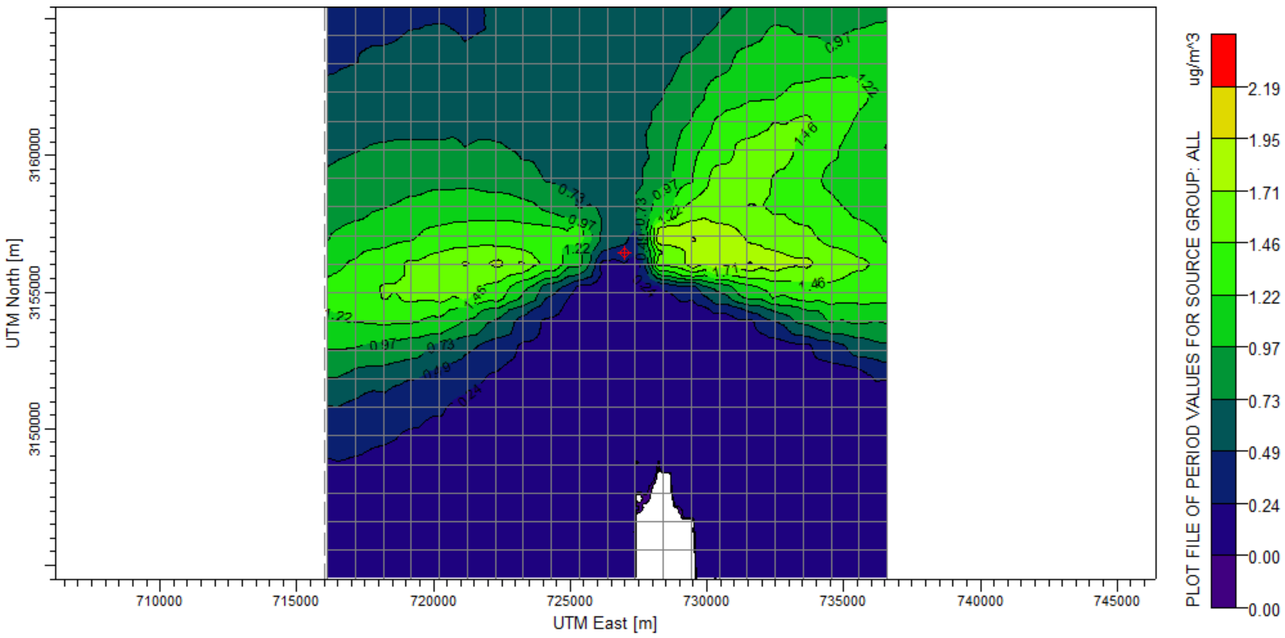


Figure 9.6-24 Predicted Ground Level Concentration of SO_2 Concentration (Annual average)

The predicted results for NOx, PM_{10} and SO_2 concentrations for the project indicated the minor or negligible increment over the baseline condition due to proposed techniques of thermal power plants. Hence it could be concluded that the increment in the baseline concentration of NOx, PM_{10} and SO_2 due the proposed TPP will be marginal. The details of increment in pollutant concentration are given below in Table 9.6-2 and Table 9.6-3, respectively.

Table 9.6-2 Increment in Background Pollutant Concentration due to Proposed TPPS

Sl. No.	Pollutant	Background Concentration, (μg/m^3)*	24 hour average Maximum GLC at (X= 733526m, Y= 3152886m) in South West direction (μg/m^3)	24 hour average concentration after Project operation (μg/m^3)	Increment (%)	NAAQS (μg/m^3)
1	NOx	35.4	23.4	58.8	39.80%	80
2	SO_2	16.7	21.2	37.9	55.94%	80
4	PM	333	7.1	340.1	2.09%	100

*Source apportionment study on Delhi City by CPCB, 2010

Table 9.6-3 Predict Concentration of NOx, SO_2 and PM10 at different Time Scale

Times average	NOx (μg/m^3)	SO_2 (μg/m^3)	PM_{10} (μg/m^3)
1 hour	70.28	61.12	21.08
8 hour	43.13	35.57	12.94
24 hour	23.56	21.05	7.1
Wnter average	4.15	2.63	0.87
Summer average	4.81	4.69	1.44
Annual average	2.25	2.19	0.68

Reference:

- CPCB, Air quality monitoring, emission inventory and source apportionment study for Indian cities, National Summary Report, Central Pollution Control Board, New Delhi, India (2010).
- S.D. Attri, S. Singh, B. Mukhopadhyay and A.K. Bhatnagar, Atlas of hourly mixing height and assimilative capacity of atmosphere in India. Met. Monograph No. Environment Meteorology-01/2008, Indian Meteorological Department, New Delhi, Govt. of India (2008).
- USEPA (U.S. Environment Protection Agency), 1995. User's Guide for the Industrial Source Complex (ISC3) Dispersion Model (Revised). Volume II - Description of Model Algorithms. EPA-454/b-95-0036.

7) Overall Comparison

For the purpose of comparison between the existing and post replacement period, emission input parameters and ground level concentration and its distance are indicated in Table 9.6-4 and Table 9.6-5 respectively. As noticeable in Table 9.6-4, GLC decreases approximately 38% in SOx, 55% in NOx and 61% in Soot & Dust.

Table 9.6-4 Comparison of Stack Emission at Source

		After Replacement			Before Replacement		
		660 MW	660 MW	Total	3x95MW	2x210MW	Total
Exht Gas Qty	m^3N/h	2,260,000	2,260,000	4,520,000	975,900	1,438,200	2,414,100
Exht Gas Temp	℃	90	90	–	90	90	–
Exht Gas Velocity	m/s	23.4	23.4	–	23.4	23.4	–
Actual Height of Outlet	m	150	Set	–	150	150	–
Emission SO2	g/h	226,000	226,000	452,000	585,540	862,920	1,448,460
Emission NOx	g/h	226,000	226,000	452,000	585,540	862,920	1,448,460
Emission Soot & Dust	g/h	67,800	67,800	135,600	97,590	143,820	241,410
		Numerical value at BMCR					

Table 9.6-5 Comparison of Maximum GLC and Distance

			After Replacement (1)			Before Replacement (2)			Savings
			660 MW	660 MW	Results	3x95MW	2x210MW	Results	[%]
Chimney Effective Height		(m)	304	304	–	239	265	504	(2)-(1)
Maxm GLC Cmax	Sulphur Oxides Sox(μg/m^3)	1hourly value	8.38	8.38	47.87	35.03	42.11	77.14	37.9%
		24 hourly value	6.70	6.70	38.29	28.03	33.68	61.71	37.9%
	Nitrogen oxides Nox(μg/m^3)	1hourly value	8.38	8.38	34.40	35.03	42.11	77.14	55.4%
		24 hourly value	6.70	6.70	27.52	28.03	33.68	61.71	55.4%
	Soot & dust (μg/m^3)	1hourly value	2.51	2.51	5.03	5.84	7.02	12.86	60.9%
		24 hourly value	2.01	2.01	4.02	4.67	5.61	10.29	60.9%

9.7 Environment and Social Assessment Points as per JICA Guidelines

Table 9.7-1 Permits and Approvals, Explanations

Sl. No.	Items	EIA and environmental permits
1	EIA and environmental permits	Environmental permits required : Environmental Clearance from Ministry of Environment and forest & Climate change Consent to Establish and Consent to Operate from State Pollution Control Board
2.	Explanations to the public	Public disclosure by the Ministry (Ministry of Environment and forest & Climate change through their website

Table 9.7-2 Anti – Pollution measures

Sl. No.	Items	Measures
1.	Air quality	**Construction Phase-** Water sprinkling for fugitive dust suppression as a result of movement of vehicles, topsoil removal, excavation etc. Low sulphur fuel with necessary control will be used in D.G sets as per the requirement. Material transportation shall be carried out in tarpaulin covered vehicles only to avoid fugitive emission and restricted to daytime only. Measures shall be taken to use vehicles and machinery having valid Pollution Under Control (PUC) certificate. **Operation Phase-** Provision through stack for proper dispersion of flue gas in the atmosphere. Green belt shall be developed to arrest the emission within the plant boundary. Adoption of Flue gas Desulphurisation (FGD) as control measures to reduce the SO_2 level from flue gas before releasing in the atmosphere. Adoption of Selective Catalytic Reduction (SCR) as control measure to reduce the NOx level from flue gas before releasing in the atmosphere.
2.	Water Quality	**Construction Phase-** Domestic waste water generated from labour camps shall be channelized to soak pits and sceptic tanks through sealed pipes. Construction waste water generated shall be suitably discharged through proper drainage system after ensuring it free from suspended debris, grit, bentonite, grease, oil etc., through proposed catch pit/oil interceptors at the outlet of the drains. **Operation Phase-** Proposed project is designed on ‘Zero discharge” concept. Waste water generated shall be suitably treated in proposed STP with advanced technology (eg. Nano bubble technology for secondary and tertiary treatment) and treated water shall be reused in plant operations. Water from CW system operated at higher CoC shall be used for Cooling water make-up, Portable water, HVAC make-up, Hydrant etc.
3.	Solid Waste	**Construction Phase-** Domestic solid waste generated from labour camp shall be collected and segregated at source and disposed at pre-designated sites through authorised vendor. Construction debris after dismantling of existing units viz, untreated wood, brick, concrete block, pipes, steel shall be reused to the maximum extent possible. Unsuitable soil, sand, gravel etc., after dismantling shall be used for levelling of low-lying areas and landfill sites if available. Other solid wastes viz, asphalt, batteries, machinery spare parts shall be disposed through nearest CPCB approved authorised recycler. **Operation Phase-** Major solid waste generated will be in the form of ash (mostly Fly ash + bottom ash+ economiser ash) 100% ash utilisation shall be achieved in first 4 years of plant operation as per MoEF guidelines. Fly ash shall be collected through ESP and conveyed in dry form and stored in the fly ash silos and subsequently transported in sealed trucks for utilisation in cement industries. An ash pond is proposed of 895 acres to handle the surplus ash during exigencies.

Sl. No.	Items	Measures
4.	Noise & Vibration	**Construction Phase-** Noise generated shall be mostly from operating heavy construction machineries, operating vehicles, D.G sets etc. It will be ensured adherence of noise level within the permissible levels prescribed by competent authority. Provision of acoustic chamber/enclosure for operating D.G sets, pumps is proposed to keep the noise level to minimum. Wearing of Ear plugs by workers shall be ensured while operating high noise generating equipment's like drillers, Jack/pneumatic hammer. Rubber padding shall be provided to reduce vibration generated from D.G sets, pumps and other heavy machinery. **Operation Phase-** Green belt of 3 tiers shall be developed to attenuate the ambient noise levels in the vicinity of the proposed TPP. Mufflers and resonators shall be installed to reduce the noise levels of the engines exhaust pipes. Control room of turbine, boiler etc., shall be acoustically designed so as to keep the noise level to minimum extent possible.

Table 9.7-3 Natural Environment

Sl. No.	Items	Impact Assessment
1.	Protected Area	Significant impact on Asola Wildlife Sanctuary (6 Km) and Okhala Bird Sanctuary (3 Km) is not envisaged.
2.	Ecosystem	Ecosystem impact beyond the existing baseline is not anticipated.
3.	Hydrology	No significant impact on hydrology is envisaged
4.	Topography and geology	Existing topography will get modified. However, geology will remain unaffected.

Appropriate mitigation will need to be planned in advance as short –term and long-term measures during environment impact stage.

Table 9.7-4 Social Environment

Sl. No.	Items	Impact Assessment
1.	Living & Livelihood	With the adoption of better technology ambient air quality is expected to improve. Quality and reliability of power supply will be assured. This will lead to: - Better education & learning opportunities - Growth in economic activities and per capita earning and over all economic upliftment of the area - Improved community health and medical facilities - Better transport and communication facilities - Improved sanitation and drainage facilities - Uninterrupted power supply - Availability of better drinking water supply - New manufacturing units like cement, gypsum, electrical products, garments etc. will come up - Growth in services (like retails, automobile workshops etc.) and increase in employment and trade opportunities in service sector - Better connectivity to Banking and Credit networking system. - Improved law and order situation - Better risk assessment and disaster management plan - Provision of environmentally safe camping area for labourers Therefore, availability of stable and reliable electricity will bring a significant change for the better in the life and living condition of the locals and open up new opportunities for various new activities.
2.	Heritage	South Delhi district has rich cultural heritage. Famous historical monuments and tourist places are Qutab Minar, Tughlaqabad Fort, ISKCON Temple, Bahai (Lotus Temple) and Chattarpur Mandir. Replacement of new TPP will not have any impact on heritage site and areas of unique archeological, historical and cultural values.
3.	Landscape	The project is to replace old, outdated power generation units with modern 2 × 660 MW Power plant based on Ultra super critical technology. The project will not have any adverse impact on the existing landscape.
4.	Ethnic Minorities and indigenous People	There are no Ethnic minorities or Indigenous people residing in the study area.
5.	Working Conditions (Including occupational safety)	With reliable power supply there will be marked improvement in working conditions in the industries in term of occupational health and safety. There will be adequate sanitation facilities for workers at site to protect the human health and avoid environmental pollution. Regular hands-on trainings, workshops and awareness camps will be organised on health and safety to ensure vibrant and safe environment to workforce.
6.	Resettlement Issues	No need for additional land. Hence, there are no rehabilitation and resettlement issues involved.

Table 9.7-5 Others

Sl. No.	Items	Impact Assessment
1.	Impact during construction	When the new 2 × 660 MW power plant comes into operation after dismantling and disposal of old plant, adverse environmental impacts in terms of air quality, water quality, noise etc. are not expected. However, during demolition of the old plant and construction of new plant there could be short term and localized adverse impacts, such as, ➢ Generation of dust and smoke due to construction, movement of vehicles, gases from engine exhaust, noise from movement of material personnel, etc. ➢ Generation of high decibel noise Pollution of water ➢ Disturbance and annoyance to the local population ➢ Inconvenience to the commuters To mitigate these temporary impacts arrangements will be made for sprinkling of water at regular intervals, maintaining of temporary roads, proper maintenance of vehicles and construction equipment covering the trucks carrying debris and construction materials with tarpaulin. Therefore, it is also suggested that a through and detailed planning needs to be done and proper mitigation measures should be adopted to ensure that the adverse impacts are kept within manageable tolerance.
2.	Accident prevention measures	Proper risk zonation of the construction site shall be prepared taking into consideration the accident prone areas. Safety measures will include: • Safety trainings like handling of tool kits, use PPE (personal protective equipment's viz safety Jackets, boots, belts, goggles, helmets, safety gloves, nose and ear mask etc.), shall be organized for workers. • Occupational health and safety trainings to workers viz., HIV, Malaria etc., shall be organized for workers working at project site. • Fire safety measures like Extinguisher, Fire hose, Fire alarm, evacuation plan etc. • Emergency evacuation plan in case of natural disaster like earthquake, tsunami etc. • Arrangements of necessary illumination for workers working during night shifts. • Proper scaffolding, shuttering, arrangement shall be carried out for all civil construction work • Safety measures like ambulance, first aid box, doctors shall be readily available for emergency situation. • Regulated management and movement of vehicles, construction equipment etc. • Safety storage of hazardous/flammable materials • Restricted access to accident prone areas • Any other safety requirements as required under the local laws.

Sl. No.	Items	Impact Assessment
3.	Monitoring	Monitoring of Bio-Physical environment shall be carried out under following three stages **Preconstruction/Baseline Phase:** Monitoring of physical environment viz. air quality, water quality, noise, soil etc. shall be carried out to study the baseline condition of the environment. **Construction Phase:** Impact during the construction phase shall be quantified by conducting monitoring of the same parameters and accordingly suitable mitigation measures shall be taken. **Operation Phase:** Monitoring shall be conducted for the above parameters to assess the reduction/escalation of pollution on the environment in terms of different environment sensitive indicators.

CHAPTER 10

FINANCIAL ANALYSIS

CHAPTER 10
FINANCIAL ANALYSIS

10.1 Financing & Project cost estimate

10.1.1 Financing

As a replacement project of coal fired thermal power station in India, Badarpur thermal power station is chosen as a model case. Economic efficiency of the project is calculated based on assumptions of construction cost, operation and maintenance cost, fuel cost and so on.

The following 3 cases are assumed for evaluation:

<Case>

(1) JICA ODA loan

(2) JBIC loan

(3) Bank loan from domestic commercial bank

The following Table 10.1-1, Table 10.1-2, Table 10.1-3 show assumptions of financing conditions, provided that Debt-Equity ratio is fixed as 7:3 in all cases in accordance with CERC guideline.

(1) JICA ODA loan

Table 10.1-1 JICA ODA loan

Loan amount	70% of project cost
Interest rate	1.4% p.a (fixed rate)
Repayment period	25 years (Grace Period : 7 years)
Repayment Condition	Equal principal payment

Source: NEDO study team

(2) JBIC loan

Table 10.1-2 JBIC loan

Loan amount	70% of project cost
Interest rate	3%* *Fixed rate for Japanese yen and floating rate for other currencies. *Including risk premium determined by borrower's credit, pledge, guarantee and scheme of the loan.
Repayment period	12 years (deferred repayment period : 2 years)
Repayment Condition	Equal principal payment

Source: NEDO study team

(3) Bank loan

Table 10.1-3 Bank loan

Loan amount	70% of project cost
Interest rate	11% p.a
Currency	Indian Rupee
Repayment period	12 years
Repayment Condition	Equal principal payment

Source: NEDO study team

10.1.2 Project cost

The following Table 10.1-4 shows results of project cost calculation of 3 cases:

Table 10.1-4 Project cost

(Unit: Crore Rupees)

	Japanese ODA loan	JBIC loan	Bank loan
Construction cost	10,709	10,709	10,709
Interest during construction	252	552	2,246
Total construction cost	10,961	11,261	12,955

Source: NEDO study team

10.2 Financial evaluation

In general, project feasibility is evaluated from technical and economic/financial aspects. A comprehensive financial model is set up to calculate financial evaluation based on construction cost and expected income.

10.2.1 Assumptions

The following Table 10.2-1 shows assumptions for evaluation.

Table 10.2-1 Assumptions of evaluation

Gross capacity (MW)	2 × 660 MW		
Project cost (Crore Rupees)	Japanese ODA Loan 10,961	JBIC Loan 11,261	Bank Loan 12,955
Construction period	54 months		
Gross thermal efficiency	44.7% (Lower heating value)		
Load factor	85%		
Auxiliary consumption	5.75		
Operating period	25 years		
Coal price	5,000Rs/MT		
Exchange rate	1USD=106.43JPY 1USD=66.729 IDRs		
Discount rate (%)	12		

Source：NEDO study team

10.2.2 Profitability of the project

(1) IRR

The following Table 10.2-2 shows results of IRR calculation.

Table 10.2-2 IRR calculation

(unit:%)

	Japanese ODA Loan	JBIC Loan	Bank Loan
Project IRR	13.0	10.8	9.4

Source: NEDO study team

The project has decent profitability in all cases. Especially in “Japanese ODA loan” case, it has high profitability.

(2) Cost of generation & Levelised tariff

Cost of generation and Levelised tariff are calculated based on CERC guideline as of February 2014. The following Table 10.2-3 indicates result of Cost of generation and Levelised tariff.

Table 10.2-3 Cost of generation & Levelised tariff

(Unit: Rupee/kWh)

	Japanese ODA Loan	JBIC Loan	Bank Loan
Cost of generation (1st year)	3.95	4.10	4.60
Levelised Tariff	3.96	4.25	5.19

Source: NEDO study team

(3) Sensitivity analysis

Sensitivity analysis is performed under the following conditions:

Case 1: Coal price varies from -10% to +10%

Case 2: Load factor varies from -5% to +5%

The following Table 10.2-4 expressed the results of Sensitivity analysis.

Table 10.2-4 Sensitivity analysis

Case 1

(Unit: Rupee/kWh)

	Japanese ODA Loan	JBIC Loan	Bank Loan
IRR	12.6% ~ 13.4%	10.4% ~ 11.2%	9.0% ~ 9,8%
Cost of generation (1st year)	3.70 ~ 4.21	3.85 ~ 4.36	4.35 ~ 4.85
Levelised tariff	3.69 ~ 4.22	3.99 ~ 4.51	4.93 ~ 5.45

Source: NEDO study tea

Case 2

(Unit: Rupee/kWh)

	Japanese ODA Loan	JBIC Loan	Bank Loan
IRR	12.8% ~ 13.3%	10.5% ~ 11.0%	9.2% ~ 9.6%
Cost of generation (1st year)	4.04 ~ 3.88	4.19 ~ 4.02	4.72 ~ 4.49
Levelised tariff	4.03 ~ 3.89	4.34 ~ 4.16	5.35 ~ 5.05

Source: NEDO study team

CHAPTER 11

INFLUENCE OF ENVIRONMENTAL IMPACT

CHAPTER 11
INFLUENCE OF ENVIRONMENTAL IMPACT

11.1 Greenhouse gas (CO_2) reduction effect

11.1.1 Greenhouse gas (CO_2) reduction effect

The object of study is an existing coal fired power station located in neighboring area of Delhi. This power station, which is owned by national power generation company NTPC Limited, consists of 5 units, whose capacities are 95 MW × 3 and 210 MW × 2, respectively. Total capacity is 705 MW. Japan team examines a feasibility of replacing this power station into high-efficient and environment conscious USC (Ultra Super Critical) coal fired power station.

This survey was conducted as follows:

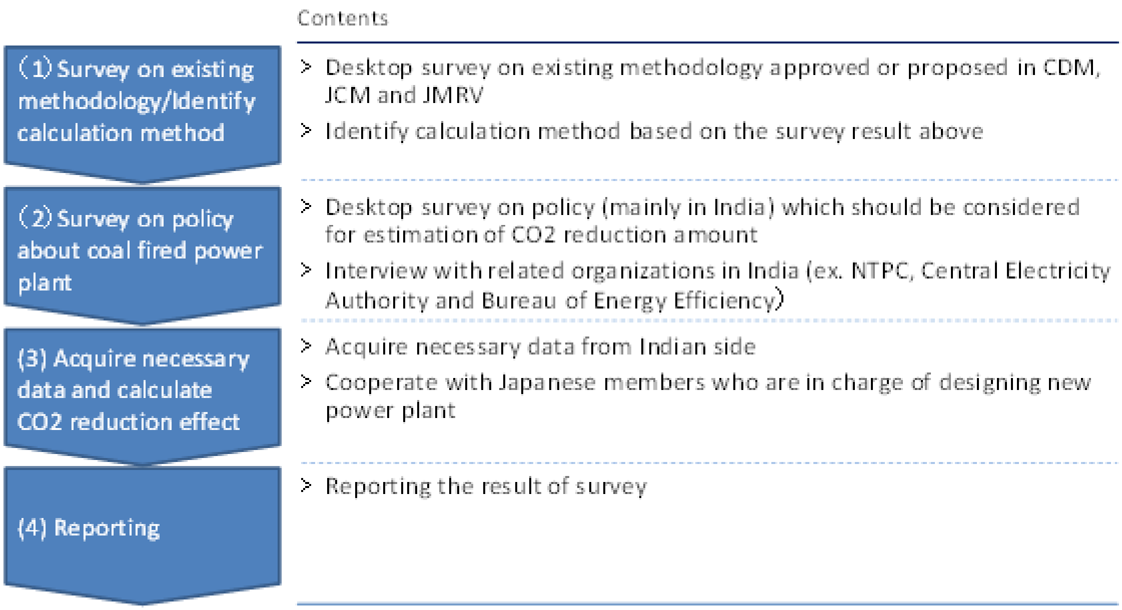


Figure 11.1-1 Flow of this survey

The most important point in this study is setting "baseline" which will be compared with actual emission amount of replaced power station. We set various options for baseline this time and calculated CO_2 reduction effect for each option. The results vary from approximately 400,000 tCO_2 per year to 6,000,000 tCO_2 per year depending on the setting of baseline scenario.

11.1.2 Existing Methodology for Calculating CO_2 Reduction Effect

At first, existing methodologies were surveyed for the reference of identifying calculation method to be applied this time. We surveyed methodologies approved or proposed in Clean Development Mechanism (CDM), Joint Crediting Mechanism (JCM) and JMRV.

(1) Clean Development Mechanism（CDM）

There are many methodologies in CDM, but few of these are applicable for a project of installation of large scale fossil fueled power plant. ACM0013 (Consolidated baseline and monitoring methodology for new grid connected fossil fuel fired power plants using a less GHG intensive technology) is one of the example.

Project emission amount is calculated by multiplying fuel consumption amount, calorific value of fuel (weighted average) and CO_2 emission factor of fuel. As for calorific value of fuel, both project specific value and default value set by IPCC are available. Default value set by IPCC is available for emission factor of fuel.

On the other hand, baseline emission amount is calculated by multiplying net electricity generation amount and baseline CO_2 emission factor (per electricity generation amount). The important point is setting baseline CO_2 emission factor. Following Approaches are prepared:

Approach 1: The emission factor of the technology identified as the most likely baseline scenario under the "Identification of the baseline scenario" section

This methodology refers to "Identification of the baseline scenario" which explains methodology for setting baseline emissions by efficiency of reference power plant as follows:

$$EF_{BL,CO2} = 3.6 \times \frac{EF_{FF,CO2}}{\eta_{BL}}$$

Where:

$EF_{BL,CO2}$	=	Baseline emission factor (t CO_2/MWh)
$EF_{FF,CO2}$	=	CO_2 emission factor of the fossil fuel type used in the project and the baseline (t CO_2/GJ)
η_{BL}	=	Energy efficiency of the power generation technology that has been identified as the most likely baseline scenario
3.6	=	Unit conversion factor from GJ to MWh

Source: Approved consolidated baseline and monitoring methodology ACM0013

Construction and operation of new grid connected fossil fuel fired power plants using a less GHG intensive technology Version 05.0.0

"Identification of the baseline scenario" consist of 3 steps below:

- ✓ Step 1: Identify all new power plants similar to the project activity
- ✓ Step 2: Determine the market share of each technology
- ✓ Step 3: Identify the baseline technology

The most important step is “Step3”. Two procedures below are shown as example:

- ✓ Sort the market share of the technologies (e.g. subcritical technology, supercritical technology, and ultra-supercritical technology), as ranked in the definition section of this methodology.
- ✓ Add up the market shares of each technology one by one from the end of the least efficient technology until the subtotal of market shares reaches 80% in terms of planned generation capacity. The technology at the 80th percentile within this subset shall be selected as the baseline technology.

Approach 2: The average emissions intensity of all power plants j, corresponding to the power plants whose performance is among the top 15% of their category, using data from the reference year v, and taking into account the technological development that would likely have occurred in the time between the investment decision on the power plants j and the investment decision on the project activity

Approach 2 is setting baseline by following manner: 1) identifying similar power plants and pick up the top 15% of those in terms of efficiency 2) assuming technological improvement. Details are as follows:

$$EF_{BL,CO2} = \frac{EF_{FF,CO2}}{\eta_{avg,j} + \Delta\eta} \times 3.6$$

with

$$\eta_{avg,j} = 3.6 \times \frac{\sum_j EG_{j,v}}{\sum_j \left(FC_{j,v} \times NCV_{j,v}\right)}$$

$EF_{BL,CO2}$	=	Baseline emission factor (t CO_2/MWh)
$\eta_{avg,j}$	=	Weighted average efficiency of power plants *j* (dimensionless)
$\Delta\eta$	=	Efficiency improvement for newly constructed power plants that would likely have occurred due to technical development in the time between the investment decisions made for the power plants *j* and the investment decision made for the proposed project activity (dimensionless)
$FC_{j,v}$	=	Amount of fuel consumed by power plant *j* in the reference year *v* (Mass or volume unit per year)
$NCV_{j,v}$	=	Average net calorific value of the fossil fuel type consumed by power plant *j* in the reference year *v* (GJ/Mass or volume unit)
$EF_{FF,CO2}$	=	CO_2 emission factor used in the project and the baseline (t CO_2/GJ)
$EG_{j,v}$	=	Net electricity generated and delivered to the grid by power plant *j* in the reference year *v* (MWh/yr)
j	=	The top 15% performing power plants as identified below, among all power plants in the geographical area as identified in Step 1.3

The important points here are 1) ηavg,j (Weighted average efficiency of power plants j) and⊿η (Efficiency improvement for newly constructed power plants) .

η avg,j is the average efficiency of the top 15% power plant similar to the project power plant. Δη does not need to be considered if the time difference between the similar power plants identified and the project power plant (considered as zero) is below 1 year. If it is above 1 year, Δη shall be calculated by following manner: 1) referring to the efficiency improvement trend of comparable power plants, 2) using default value (0.3% improvement per year).

(2) Joint Crediting Mechanism（JCM）

Joint Crediting Mechanism (JCM) is the bilateral offset mechanism implemented under the agreement between Japanese government and host country government. JCM has started its operation but there is no approved methodology applicable to the project for fossil fueled power plant. We surveyed methodologies proposed in the feasibility study which is supported by Japanese government.

JCM adopts the concept of “Reference Emission” which corresponds to “Baseline Emission” in CDM. Reference emission is defined as follows: “Reference emissions are calculated below business-as-usual (BaU) emissions which represent plausible emissions in providing the same outputs or service level of the proposed JCM project in the host country”.

(3) FY2011 NEDO Global Warming Mitigation Technology Promotion Project “Program organization research on efficiency enhancement project of coal-fired thermal power plant in the Republic of India” (Idemitsu Kosan / Mizuho Corporate Bank)

In this study, for the purpose of the reduction of CO_2 emissions in aging thermal power plants in India, combustion optimization, retrofit of Boiler Auxiliary Machinery, turbine rehabilitation and coal cleaning are investigated. Two calculation approaches for baseline emissions are proposed in this FS, 1) Using actual fuel consumption amount after implementing project, 2) Using net electricity generation amount after implementing project.

In the approach 1), baseline emissions are calculated by multiplying fuel consumption amount (TJ), emission factor of fuel (tCO_2/TJ), thermal efficiency ratio (between average heat rate before project implementation and heat rate in year y) and PAT target.

$$BE_y = \sum_i \left(PC_{fuel,i,y} \times EF_{fuel,i,y}\right) \times \frac{SHR_{BE}}{SHR_{PE,y}} \times PAT_y$$

BE_y =	Baseline emissions in year y (tCO2/y)
$PC_{fuel,i,y}$ =	Total amount of fuel type i consumed in year y (TJ/y)
$EF_{fuel,i,y}$ =	Emission factor of fuel type i consumed in year y (tCO2/TJ)
SHR_{BE} =	Average Station Heat Rate before project implementation for xx years(kcal/kWh)
$SHR_{PE,y}$ =	Station Heat Rate in year y (kcal/kWh)
PAT_y =	PAT target in year y (%)

On the other hand, in the approach 2), baseline emissions are calculated by multiplying net electricity generation amount, CO_2 emission factor of electricity (tCO_2/MWh), and PAT target. As for CO_2 emission factor, using the data published by CEA is assumed.

$$BE_y = PC_{elec,y} \times EF_{elec,y} \times PAT_y$$

BE_y =	Baseline emissions in year y (tCO2/y)
$PC_{elec,y}$ =	Net power generation in year y (MWh/y)
$EF_{elec,y}$ =	Baseline emission factor (tCO2/MWh)
PAT_y =	PAT target in year y (%)

In this report, they mentioned necessity of reconsideration of baseline as follows: “Taking into consideration the fact that the chronic shortage of electricity in India, it is not reasonable to regard the transition from existing power plants to new power plants as a baseline scenario. Although reasonable baseline scenario is “keep using existing power plants in the same efficiency”, we should reconsider the baseline scenario because PAT scheme is to be applied in the power plant. ”

(4) FY2012 NEDO Global Warming Mitigation Technology Promotion Project, ”Studies for Project Follow-up Study for Project Development and Organization Introduction of an ultra-supercritical coal-fired power plant in Vietnam”, Mitsubishi Research Institute Inc.

This FS followed up the FS conducted in FY2011 whose theme was ultra super critical (USC) coal fired power plant construction project in India. The purposes of this FS are to overcome problems identified through last year's study and to promote introducing an USC coal fired power plant.

Two calculation approaches for reference emissions are proposed in this FS, 1) using reference emission factor calculated by thermal efficiency estimated by coal quality and performance of commercial sub-critical power plant or actual performance data acquired from power plants built in recent 3 years, 2) using reference emission factor calculated by actual thermal efficiency of all power plants connected to the grid in the area, which would be updated in every monitoring report.

Approach 1) calculates reference emission amount by dividing coal emission factor by thermal efficiency of reference technology and multiply numerical value of 3.6. Thermal efficiency refers to designed heat rate or actual performance. Approach 2) calculates reference emission amount by multiplying fuel consumption amount, net calorific value of coal, and emission factor of coal. As for net calorific value of coal and emission factor of coal, data described in invoice, actually measured data, and default value set by Government of India or IPCC can be used.

(5) FY2012 NEDO Global Warming Mitigation Technology Promotion Project, ”Studies for Project Follow-up Study for Project Development and Organization Introduction of an ultra-supercritical coal-fired power plant in Vietnam”, Mitsubishi Research Institute Inc.

This is a feasibility for installation of the first Ultra Super Critical (USC) coal fired power plant in Viet Nam.

In this FS, MRV methodology which calculates CO_2 emission amount by dividing CO_2 emission factor of coal by thermal efficiency of reference power plant technology and multiply numerical value of 3.6 was proposed. Although the use of default value is recommended, plant specific data is also admitted to use if they can meet the required monitoring conditions.

The important issue pointed out in this report is identification of reference power plant technology. As for this point, following two approaches were prepared: 1) power plants built in recent 5 years, 2) power plants to be built in next 5 years. As for approach 1), three options, namely, A. thermal efficiency of most used technology in reference power plants, B. weighted average of thermal efficiency of reference power plants, C. highest thermal efficiency among reference power plants. In the case of approach 2), A and C is set by the same manner as approach 1), B is average thermal efficiency quoted from FS.

Reference scenario is defined as "installing lower efficient coal fired power plant technology than project technology". This is based on the recognition of the fact that currently there is no plant of installing USC and all of the existing power plants are Sub Critical.

(6) FY2014 METI Global Warming Mitigation Technology Promotion Project, "Highly-efficient power generation in Chile", Mitsubishi Research Institute Inc.

This is a feasibility study about installation of Integrated Gasification Combined Cycle in Chile.

In this FS, MRV methodology which calculates reference emission amount by multiplying net electricity generation amount and emission factor of reference power generation. Emission factor is calculated by dividing reference CO_2 emission amount by net project electricity generation amount. Reference CO_2 emission amount is calculated by multiplying coal consumption amount of reference power plant, calorific value of coal, emission factor of coal, oxidation factor (1.0 for coal) and 12/44 (conversion from C to CO_2).

As for reference scenario, following concept is proposed: BAU is installation of Sub Critical coal fired power plant and reference scenario can be considered as achieving efficiency improvement at BAU (X% improvement per year). The reason for this concept is that currently only Sub Critical power plant exists in Chile and there would be no change of situation until 2020 judging from construction plan.

(7) J-MRV

JBIC (Japan Bank for International Cooperation) has launched the "Global action for Reconciling Economic growth and Environmental preservation (GREEN)" to support projects aiming to prevent global warming. For this financial instrument, JBIC also established Guidelines for Measurement, Reporting and Verification of greenhouse gas (GHG) Emission Reductions in JBIC's GREEN (the "J-MRV Guidelines[1]").

J-MRV Methodology No.4 "Methodology for Power Generation Projects Using Low-Carbon Technology for Fossil Fuel" is applicable for fossil fueled power plant project. Project emissions are calculated by multiplying fuel consumption amount, calorific value of fuel, and CO_2 emission factor of fuel. Project specific value is used for calorific value. Default value defined in this guideline is used for CO_2 emission factor.

On the other hand, baseline emission is calculated by multiplying project electricity generation amount and CO_2 emission factor of electricity. Both gross electricity generation amount and net electricity generation amount are available for this calculation.

The concept of emission reduction is separated into 2 concepts namely "A. Construction of new power plants" and "B. Rehabilitation of existing power plants".

In the case of A, emission reduction amount is defined as "the difference between the amount of emission when the same amount of power generated by using low-carbon technology used by

[1] "Guidelines for Measurement, Reporting and Verification of GHG Emission Reductions in JBIC GREEN Operation ("J-MRV Guidelines")" Revised, August 2015 Japan

the project was generated by the average emission factor of electricity in the country (baseline emissions) and the amount of emission from the project activity (project emissions)". Generally, using emission factor of all power plant are recommended, but there is an exception mentioned as follows: "However, when there are fuel supply constraints such as the energy policy of the country or the economics of the projects in the country, the baseline emissions are the average emission factor of the same fuel type as in the project activity." Available emission factors are prepared in the guideline. This guideline also points out that "In the case where there are regulations / standards / guidelines or international standards in the country with regard to baseline emissions, those are taken into account as factors in accounting the baseline emissions. However, if the project activity is under the government's transitional measures, those factors are considered based on the project nature".

In the case of B (rehabilitation), emission reduction amount is defined as "the difference between the amount of emission from the fossil fuel fired power generation plant before the project is implemented (baseline emissions) and the amount of emission from the project activity (project emissions)". Emission factor is calculated by dividing emission factor of fossil fuel by actual thermal efficiency of power plant before rehabilitation and multiply numerical value of 3.6 (GJ/MWh).

(8) Options for Calculation of CO2 Emission Reduction

As we see in the result of survey for existing or proposed methodology, calculation for project emission amount is almost the same among the methodologies. This is calculated by multiplying fuel consumption amount, calorific value of fuel and CO_2 emission factor of fuel. However, there are various ways proposed for setting baseline level.

In this study, we identified following 4 options to calculate baseline emissions referring to existing or proposed methodologies shown in the previous section:

	Emission Factor	Reference Methodology
Grid Emission Factor	> Use grid emission factor to which the power plant is connected	> J-MRV Methodology No.4
Energy Efficiency Target (PAT)	> Refer to energy efficiency target set by PAT (Perform, Achieve and Trade)	> Proposed by JCM FS
Performance of Benchmark Technology	> Refer to the thermal efficiency of benchmark technology (ex. Super Critical, etc)	> CDM ACM0013 > Proposed by JCM FS
(Ref) Historical performance before replacement	> Use historical operation data of power plant	> J-MRV Methodology No.4

Figure 11.1-2 Options for calculating baseline emission amount

If historical performance data is used as a baseline, emission reduction amount would be larger than the case of BaU (Business as Usual) scenario, because in BaU scenario, it is reasonable to think that PAT target would be achieved. In this report, this case is calculated only for the reference.

11.1.3 Domestic or international policies related to coal fired power plant

Current situation of domestic or international policies should be considered for identifying baseline scenario. In this study, current policies are surveyed through desktop survey and interview.

(1) PAT（Perform, Achieve and Trade）

BEE (Bureau of Energy Efficiency) has started implementation of PAT (Perform, Achieve and Trade) from 2011, in which they imposed an energy efficiency target to designated large energy consumption facilities. First cycle was implemented from 2011 to 2014 in which they cover 8 sectors, namely, aluminum, cement, chlor-alkali, fertilizer, pulp & paper, thermal power plants (TPPs), iron & steel, and textile. Total energy saving target of first cycle is 6.63 million ton oil equivalent (MTOE). Energy saving target for TPPs is 3.1 MTOE which accounts for large portion of whole target.

Energy efficiency target is set based on energy consumption intensity of each facility. If they can save more energy than target, Energy Saving Certificate (ESCert) is issued from BEE for the amount of overachievement. 1 ESCert is issued for 1 TOE saving. If they cannot meet the target, they have to purchase enough amount of ESCert to meet the target. If they cannot meet the target with purchasing ESCert, they have to pay penalty.

In the TPPs sector, Net Heat Rate (NHR, kcal/kWh) is used as energy intensity which is calculated as follows:

NHR (Kcal/Kwh) = Gross Heat Rate / (1-APC)
Gross heat rate = Total Heat Input / gross generation
APC = Auxiliary Power Consumption

Variation in Net Station Heat Rate from Design Net Heat Rate is considered to set energy efficiency target. In the first cycle, actual performance data from FY2007 to FY2009 is used for baseline. The larger the variation in net station heat rate from design heat rate, the higher target they impose as a target.

Table 11.1-1 Energy efficiency target for TPPs

Variation in Net Station Heat Rate from Design Net Heat Rate	**Reduction Target for % deviation in the Net Station Heat Rate**	**% Reduction Target in Net Station Heat Rate**
Up to 5%	10%	0.5
More than 5% and up to 10%	17%	0.85 to 1.7
More than 10% and up to 20%	21%	2.1 to 4.2
More than 20%	24%	4.8 and above

Source: NTPC

PAT first cycle covers 146 thermal power plants in India. As for NTPC, 27 power plants are designated (Coal 15, Gas 12). Badarpur thermal power station is imposed PAT energy efficiency target.

Currently, BEE are preparing to implement PAT second cycle. Details are not published but new energy efficiency target will be imposed to TPPs. Latest energy efficiency target

(2) Performance Standard

Thermal efficiency of existing power plants will be improved gradually through PAT scheme. On the other hand, there is a trend that thermal efficiency more than Super Critical is required for new power plants. In March 2015, Ministry of Power released “Initiatives to Improve the Efficiency of Coal Based Power Plants” in which they quote statement of Piyush Goyal, Minister of State with Independent Charge for Power, Coal and New & Renewable Energy as follows:

(i) Out of about 87,000 MW thermal capacity under construction, about 48,000 MW is based on supercritical technology, which uses less coal.

(ii) **Supercritical technology has been made mandatory for Ultra Mega Power Projects (UMPPs)** being implemented.

(iii) **In 13th Plan, all coal fired capacity addition shall be through supercritical units.**

(iv) An Advanced Ultra Super Critical Technology R&D Project has been approved by Government at a cost of Rs.1500 Crore involving BHEL, NTPC and Indira Gandhi Centre for Atomic Research (IGCAR) to achieve higher efficiency, reduce carbon-dioxide emissions and coal consumption for coal based power plants.

(v) Renovation, Modernization and Life Extension of old thermal power generating units and retirement of old and inefficient thermal generation units, in phased manner, is being undertaken. A total capacity of 3,000 MW has been retired till date.

(vi) Government of India have issued policy on automatic transfer of linkage in case of scrapping of old units and replacing them with new supercritical plants.

(vii) Doubling coal cess from Rs.100 per tonne to Rs.200 per tonne for funding projects under National Clean Energy Fund as announced in the Budget Speech of 2015-16.

(viii) Increasing the share of renewable energy in the overall power generation in the country.

(ix) Perform Achieve Trade (PAT) Scheme under National Mission on Enhanced Energy Efficiency is under implementation by Bureau of Energy Efficiency (BEE). In this Scheme, individual target for improving energy efficiency has been assigned to 144 number of thermal stations.

***Bold and underline** by MGSSI

Ultra Mega Power Projects (UMPP) is national power station development program in which Power Finance Corp conducts bidding and planned capacity of each power station is above 4,000 MW. 16 projects are being planned and operator has been decided in 13 of 16 projects. 2 of them has already started operation.[2]

In the latest National Electricity Plan which was published in 2013, promotion of installing Super Critical during 13th Five-Year-Plan (2017-2022) is often mentioned. Capacity addition scenario during 13th Five-Year-Plan shown in this National Electricity Plan is as follows.

[2] FY2014 JOGMEC Report Event held on March 11, 2015 http://coal.jogmec.go.jp/result/docs/150313_03.pdf

Although there is little capacity addition of Sub Critical, large amount of capacity addition of Super Critical is assumed.

Table 11.1-2 Capacity addition scenario during 13th Five-Year-Plan

	SC-1 Low Gas Low Renewables (Base Case)	SC-2 High Gas Low Renewables	SC-3 High Gas High Renewables	SC-4 Low Gas High Renewables
Hydro	12,000	12,000	12,000	12,000
Nuclear	18,000	18,000	18,000	18,000
Renewable (Excluding Solar)	14,500	14,500	25,000	25,000
Solar	16,000	16,000	20,000	20,000
Retirements of Old inefficient Units	4000	4000	4000	4000
Gas	0	13,000	13,000	0
Coal	56,400	45,200	37,200	54,800
Sub-Critical	10,000	0	0	0
Super Critical	46,400	45,200	37,200	54,800

Source: Ministry of Power, "National Electricity Plan" Dec 2013

In the meeting with NTPC, a person of NTPC mentioned that "Ministry of Environment, Forest and Climate Change may not admit a plan to build Sub Critical power plant in the critically polluted area which includes Badarpur in the review process of environmental impact assessment. In this case, power plant whose thermal efficiency is more than Super Critical is required.

(3) OECD Export Credits for Coal Fired Power Plant

In November 2015, the participants to the arrangement on officially supported export credits have agreed the sector understanding on export credits for coal fired electricity generation. In this agreement, Sub Critical power plant project cannot be supported, except for IDA (International Development Association) countries. If business operator tries to get officially supported export credits in India, thermal efficiency more than USC is required.

Table 11.1-3 Maximum Repayment Terms described in OECD Document

Plant Unit Size (Gross Installed Capacity)	Unit>500MW	Unit≥300 to 500 MW	Unit < 300MW
Ultra-supercritical (i.e., with a steam pressure >240 bar and ≥593°C steam temperature), OR Emissions < 750 g CO_2/kWh	12 years	12 years	12 years
Supercritical (i.e., with a steam pressure >221 bar and >550°C steam temperature), OR Emissions between 750 and 850 g CO_2/kWh	Ineligible	10 years, and only in IDA-eligible countries	10 years, and only in IDA-eligible countries
Subcritical (i.e., with a steam pressure < 221 bar), OR Emissions > 850 g CO_2/kWh	Ineligible	Ineligible	10 years, and only in IDA-eligible countries

Source: OECD "SECTOR UNDERSTANDING ON EXPORT CREDITS FOR COAL-FIRED ELECTRICITY GENERATION PROJECTS" Nov 2015

11.2 Calculation of CO_2 Emission Reduction Effect

11.2.1 Conditions for calculation

(1) Power Plant

Study team examines a feasibility of installing 2 units of 660 MW USC plant. Annual operation hours are 8,000 hours. Auxiliary power rate is 6%. Coal consumption amount is estimated to be 329 tons / hour per unit.

(2) Coal Quality

We refer to the coal quality data provided by JPOWER. Details are shown in the table below.

Table 11.2-1 Coal quality assumed in this study

Item	Value	Value（As Fired Basis）
High Heating Value of Coal (Air Dry)	18,070 kJ/kg 4,316 kcal/kg	17,166.5 kJ/kg 4,100 kcal/kg
Total Moisture（As Fired Basis）	12 %	12 %
Surface Moisture（As Fired Basis）	5 %	5 %
Ultimate Analysis		
Carbon (Dry)	45.34 %	39.90 %
Hydrogen (Dry)	3.7 %	3.26 %
Oxygen (Dry)	7.41 %	6.52 %
Nitrogen (Dry)	1 %	0.88 %
Sulfur (Dry)	0.5 %	0.44 %
Ash (Dry)	42.05 %	37.00 %

Source: JPOWER

CO_2 emission factor of coal is calculated based on data above.

1 - 0.12 [Total Moisture] = 0.88

0.4534 [Carbon Content (Dry Basis)] × 0.88 = 0.399 kgC / kgcoal

0.399 / 12 × 44 = **1.463 kgCO$_2$ / kgcoal** (tCO$_2$ / t coal)

1.463 (tCO$_2$ / t coal) / 17.1665 (GJ/ton) = **0.0852 tCO$_2$/ GJ**

11.2.2 Calculation of the Effect of CO_2 Emission Reduction

(1) Project CO_2 Emission Amount

Project emission amount is calculated as follows:

Project emission amount (tCO$_2$/y)
= Coal consumption amount (t/y) × CO_2 emission factor of coal (tCO$_2$/t)
= 329 tons / hour × 2 unit's × 8,000 hours / year × 1.463 tCO$_2$ / ton
= 7,701,000 tCO$_2$ / year

Project emission factor (tCO$_2$ / MWh)
= Coal consumption amount (t/h) × CO_2 emission factor of coal (tCO$_2$/tCoal)
/ Net electricity generation amount (MWh)
= 329 t/h × 1.463 tCO$_2$/tCoal / 660 MWh / (1 – 0.08)
= 0.793 (tCO$_2$ / MWh)

(2) Options for Calculation of Baseline CO_2 Emission Amount and Calculation Results

Baseline emission amount is calculated as follows:

Baseline emission amount (tCO$_2$/y) = Net electricity generation amount of project power plant (MWh / year) × Baseline emission factor (tCO$_2$ / MWh)

The important point is setting baseline emission factor (tCO$_2$ / MWh). 4 options are selected as mentioned in the previous section of this report. Here we show the calculation result of each option.

Net electricity generation amount is assumed as follows:

Net electricity generation amount of project power plant (MWh / year)
= Total capacity (MW) × Annual operation hours (hours / year) × (1 - Auxiliary Power Ratio)
= 1,320 MW × 8,000 hours × (1 – 0.08) = 9,715,200 MWh

(3) Performance Standard（Super Critical）

As mentioned before, only super critical will be adopted for new plant after 2017. According to "National Electricity Plan" (CEA, Nov. 2012), Baseline CO_2 emission of Super Critical is described as 0.88 tCO_2/MWh, Net Heat Rate is 2,326kcal/kWh.

Using this guideline, Baseline CO_2 emission is calculated as follows;

Baseline CO_2 emission = 9,715,200 MWh × 0.88 tCO_2 / MWh = **8,549,000 tCO_2 / y**

(4) Grid Emission Factor

As for grid emission factor, we refer to "CO_2 Baseline Database for the Indian Power Sector User Guide" published by CEA. The latest version is Version 10.0 published in Dec 2014.

Table shown below is grid emission factor of each grid in India.

Table 11.2-2 Grid emission factor in India

	Average	OM	BM	CM
NEWNE	0.82	1.00	0.95	0.97
South	0.82	1.02	0.96	0.99
India	0.82	1.00	0.95	0.98

Source: CEA「CO_2 Baseline Database for the Indian Power Sector User Guide」Version 10.0, Dec 2014

"Average" means an average emission factor of all power stations connected to grid. OM is an abbreviation for "Operating Margin" which is an average emission factor of all power stations excluding low cost/must run source (hydro, nuclear). BM is an abbreviation for Build Margin which is an average of power stations recently added to the grid (they account for 20% of all power generation amount of grid). CM is an abbreviation of Combined Margin which is an average of OM and BM. We apply CM of NEWNE grid to which Badarpur thermal power station is connected (**0.97 tCO_2 / MWh**).

Baseline CO_2 emission = 9,715,200 MWh × 0.98 tCO_2 / MWh = **9,521,000 tCO_2 / y**

(5) PAT

Baseline emission factor is calculated as follows:

Baseline emission factor (tCO_2/MWh) = Emission factor of coal (tCO_2/GJ) / Baseline thermal efficiency (%) × 3.6 GJ/MWh (Conversion from GJ to MWh)

In the first cycle of PAT, Badarpur thermal power station set PAT target of 2,942 kcal/kWh. Using this value, calculation of emission factor is as follows:

Baseline thermal efficiency (%) = 1 / (PAT Target （kcal/kWh） / 860 (Conversion from kcal to kWh)

= 1 / ((2,942 kcal/ kwh) / 860) = 29.2 %

Baseline emission factor（tCO_2/MWh）

= (0.0896 tCO_2/GJ) / 29.2% × 3.6 GJ/MWh = **1.103 tCO_2 / MWh**

Baseline CO_2 emission = 9,926,400 MWh × 1.103 tCO_2 / MWh = **10,950,605 tCO_2 / y**

New PAT target may be applied when new USC power plant starts its operation. Latest value of PAT should be confirmed.

1) Performance of Benchmark Technology（Super Critical）

As mentioned before, Super Critical or more efficient technology will be standard for newly built power plant after 2017, when the period of 13th Five-Year-Plan starts. In National Electricity Plan, emission factor of Super Critical is described as **0.88 tCO_2/MWh** (net) and Net Heat Rate is described as 2,326kcal/kWh as an example.

Baseline CO_2 emission = 9,926,400 MWh × 0.88 tCO_2 / MWh = **8,735,232 tCO_2 / y**

2) Reference: Historical Performance

Historical operation data from FY2012 to FY 2014 is used. Following data are provided by Badarpur Thermal Power Plant. We use coal quality data provided by JPOWER shown in Table 11.2-3.

Table 11.2-3 Historical operation data of Badarpur Thermal Power Station

	Coal Consumption (ton)	Net Power Generation (MWh)
FY2012	4,006,209	4,165,524.3
FY2013	3,545,675	3,765,938.8
FY2014	2,705,858	2,936,795.5
Total	10,257,742	10,868,358.6

Source: NTPC

Baseline Emission Factor（tCO_2/MWh） = Coal consumption amount (t) × CO_2 emission factor of coal（tCO_2/t） / Net electricity generation amount (MWh)

= 10,257,742 × 1.579 tCO_2 / ton / 10,868,358.6 MWh
= **1.491 tCO_2 / MWh**

Baseline CO_2 emission = 9,926,400 MWh × 1.491 tCO_2 / MWh = **14,796,539 tCO_2 / y**

11.3 Calculation Results of the Effect of CO_2 Emission Reduction

Based on the result of calculation of baseline CO_2 emission amount and project CO_2 emission amount, we estimated the effect of CO_2 emissions reduction as following table:

Table 11.3-1 Results of the Estimation of CO2 Emission Reduction

Options for Baseline	A. Baseline CO_2 emissions (tCO_2/y)	B. Project CO_2 emissions (tCO_2/y)	(A-B) CO_2 emission reduction (tCO2/y)
1) Grid emission factor	9,628,608	8,313,663	1,314,945
2) PAT	10,950,605		2,636,941
3) Performance of benchmark technology	8,735,232		421,569
4) Reference: Historical performance	14,796,539		6,482875

The results vary from approximately 400,000 tCO_2 per year to 6,000,000 tCO_2 per year depending on the setting of baseline scenario.

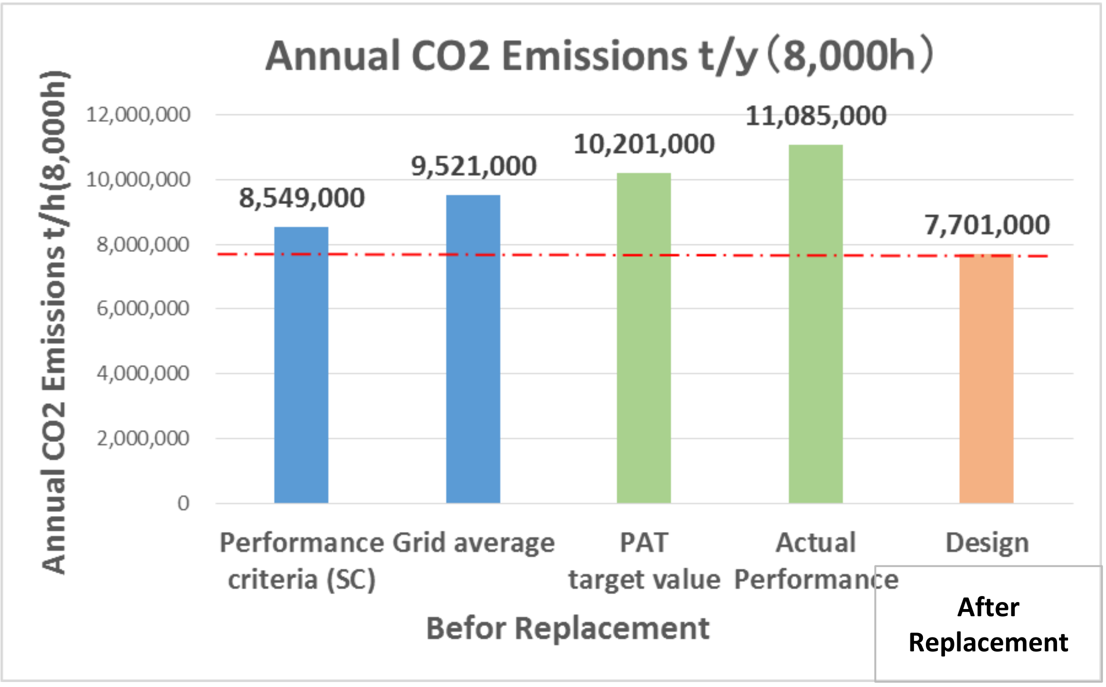


Figure 11.3-1 Comparison of CO_2 reduction effect with different baselines

CO_2 reduction effect depends on the baselines to be adopted as 850,000 tCO_2 /y (9.9%) to 3,400,000 tCO_2 /y (30.5%)

CO2 reduction effect from the baseline of performance standard (SC) is 9.9% and that from the grid emission factor is 19.1%. CO2reduction effect from current Badarpur TPS is much more than above.

11.4 Calculation of the potential of environmental impact mitigation

In this chapter, PM, NOx and SOx reduction by the replacement to latest USC (660MW × 2, 1,320MW) was calculated. As a results, environmental values by replacement to USC is expect a drastic reduction of 10 – 17% based on current sub-critical plant.

11.4.1 New Environmental Norms

New environmental norms has been introduced in India in December 2015 by MOEF&CC shown in Table 11.4-1

Table 11.4-1 New Environmental Norms

Parameters	Standards
Particulate Matter (PM)	30mg/Nm^3
Sulphur Dioxide (SO_2)	100mg/Nm^3
Oxide of Nitrogen (NOx)	100mg/Nm^3

Note: PM is converted as $CO_2$12%, SO_2, NOx are converted as $O_2$6 %

11.4.2 Emission value after replacement

In this feasibility study, environmental values after replacement are shown in Table 11.4-2.

Table 11.4-2 Environmental Values after Replacement

Parameters	Design Value
Particulate Matter (PM)	Less than 30mg/Nm^3
Sulphur Dioxide (SO_2)	Less than 100mg/Nm^3
Oxide of Nitrogen (NOx)	Less than 100mg/Nm^3

Note: PM is converted as CO_2 12%, SO2, NOx are converted as O26％

11.4.3 Current emission value

Current emission values in 2010 – 2016 are referred in DPCC（Delhi Pollution Control Committee）website (Figure 11.4-1).

DELHI POLLUTION CONTROL COMMITTEE
(Government of N.C.T. of Delhi)
4th Floor, I.S.B.T. Building, Kashmere Gate, Delhi - 110006
Website : http://www.dpcc.delhigovt.nic.in

LABORATORY INFORMATION SYSTEM

TPP Emission Reports

S.No.	Report Number	TPP Name	Report Date	Action
1	DPCC/TPP/2901	Badarpur Thermal Power Station	11-02-2016	View
2	DPCC/TPP/2880	Pragati (Gas Based) Power Station	08-02-2016	View
3	DPCC/TPP/2879	I.P. Gas Turbine Power Station	08-02-2016	View
4	DPCC/TPP/2836	Badarpur Thermal Power Station	07-12-2015	View
5	DPCC/TPP/2835	Pragati (Gas Based) Power Station	07-12-2015	View
6	DPCC/TPP/2834	I.P. Gas Turbine Power Station	07-12-2015	View
7	DPCC/TPP/2814	Badarpur Thermal Power Station	12-11-2015	View
8	DPCC/TPP/2813	Pragati (Gas Based) Power Station	12-11-2015	View
~	~	~	~	~
251	DPCC/TPP/1111	Pragati (Gas Based) Power Station	10-02-2010	View
252	DPCC/TPP/1110	Badarpur Thermal Power Station	10-02-2010	View
253	DPCC/TPP/1109	Rajghat Thermal Power Station	10-02-2010	View
254	DPCC/TPP/1094	I.P. Gas Turbine Power Station	14-01-2010	View
255	DPCC/TPP/1093	Pragati (Gas Based) Power Station	14-01-2010	View
256	DPCC/TPP/1092	Badarpur Thermal Power Station	14-01-2010	View
257	DPCC/TPP/1091	Rajghat Thermal Power Station	12-01-2010	View

Figure 11.4-1 Database in DPCC Website

Extracted data for Badarpur is shown in Table 11.4-3.

Table 11.4-3 Extracted data for Badarpur

Delhi Pollution Control Committee:
:http://www.dpcc.delhigovt.nic.in/dpcc_remote/lis/viewTPPReportsView.php
LABORATORY INFORMATION SYSTEM
Badarpur Thermal Power Station
Standard of Particulate matter- 150 mg/Nm^3
* Normalized at 12 % CO_2
** Normalized at 6 % O_2
# Shutdown/Under Maintenance

		S.No	Sampling Location	Load in MW	Stack Temp In Degree Kelvin	Flow Nm^3/hr	Concentration in mg/Nm^3		
1	11-02-2016						Particulate Matter*	Sulphur Dioxide	NOx**
1	11-02-2016	1	Unit -I A	#	#	#	#	#	#
1	11-02-2016	2	Unit -I B	#	#	#	#	#	#
1	11-02-2016	3	Unit -II A	#	#	#	#	#	#
1	11-02-2016	4	Unit -II B	#	#	#	#	#	#
1	11-02-2016	5	Unit -III A	#	#	#	#	#	#
1	11-02-2016	6	Unit -III B	#	#	#	#	#	#
1	11-02-2016	7	Unit -IV A	#	#	#	#	#	#
1	11-02-2016	8	Unit -IV B	#	#	#	#	#	#
1	11-02-2016	9	Unit -V A	200	392	534256	18.5	440	175
1	11-02-2016	10	Unit -V B	200	393	450386	21	400	223

Environmental values trend Unit1-3、Unit4,5 in recent 5yeaes are shown in Figure 11.4-2.

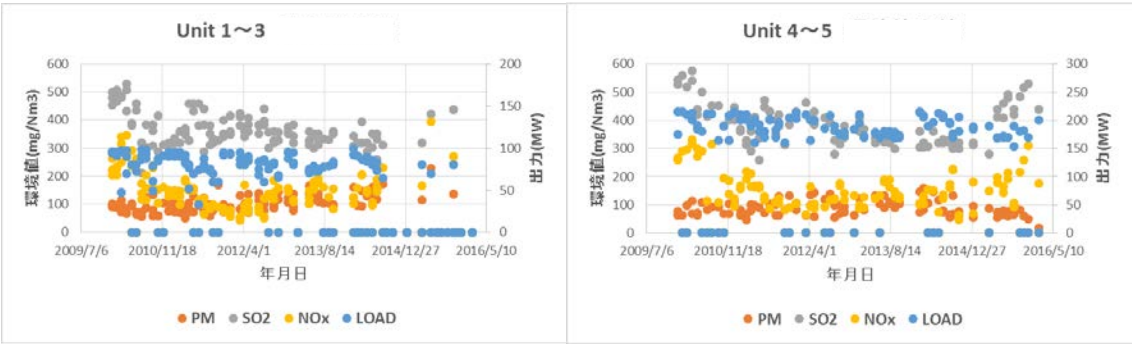


Figure 11.4-2　Environmental values trend Unit1-3、Unit4,5 in recent 5yeaes

Trend data of PM, NOx and SOx are shown in Figure 11.4-3.

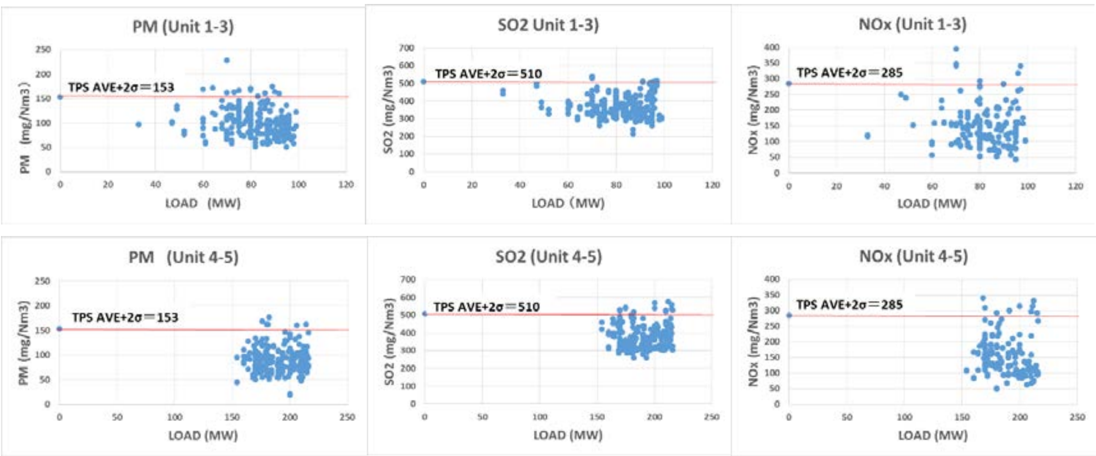


Figure 11.4-3　Trend data of PM, NOx and SOx at Badarpur TPS

Typical data as average of the trend are, PM＝153 mg/Nm^3、SO_2＝510 mg/Nm^3、NOx = 285 mg/Nm^3.

11.4.4　Estimation of environmental value by replacement

Estimation of environmental value by replacement is shown in Table 11.4-4.

Table 11.4-4　Estimation of environmental value by replacement

Parameters	Current	Replacement
Particulate Matter (PM)	153 mg/Nm^3	Less than 30 mg/Nm^3
Sulphur Dioxide (SO_2)	510 mg/Nm^3	Less than 100 mg/Nm^3
Oxide of Nitrogen (NOx)	285 mg/Nm^3	Less than 100 mg/Nm^3

Note: PM is converted as $CO_2$12%, SO_2, NOx are converted as O_2 6%

Reduction of pollutant matters by replacement and its comparison are shown in Figure 11.4-4. It is clearly indicated that remarkable reduction effect is expected.

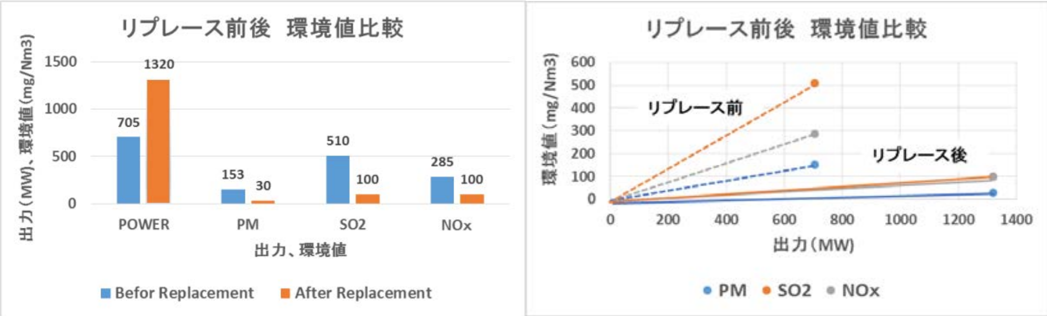


Figure 11.4-4　Reduction of pollutant matters by replacement

Reduction of pollutant matters by replacement (t/h) is shown in Table 11.4-5 and Figure 11.4-5.

Table 11.4-5　Reduction of pollutant matters by replacement (t/h)

Parameters	Current	Replacement
Particulate Matter (PM)	654 t/h	113 t/h
Sulphur Dioxide (SO_2)	2,242 t/h	377 t/h
Oxide of Nitrogen (NOx)	1,230 t/h	377 t/h

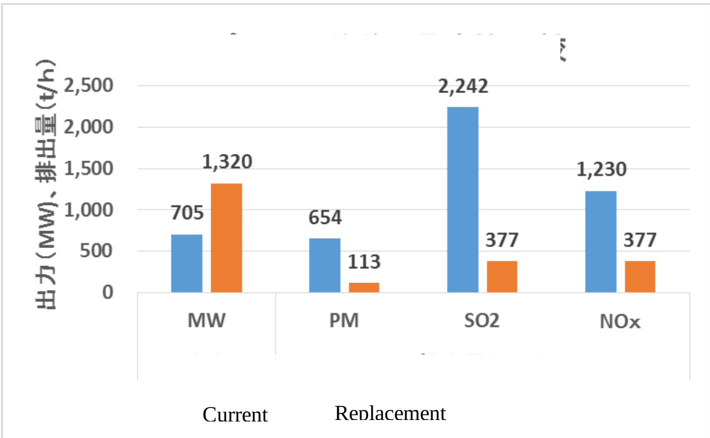


Figure 11.4-5　Reduction of pollutant matters by replacement

11.4.5 Estimation of Environmental impact by replacement

Environmental values of exsisting plants are PM of 153 mg/Nm^3, SO_2 of 320 ~ 1,150 mg/Nm^3, NOx of 285 mg/Nm^3, comparison these values with replacement is shown in Table 11.4-6 and Figure 11.4-6.

Table 11.4-6 Reduction of pollutant matters by replacement comparison with average

Parameters	Current average	replacement
Particulate Matter (PM)	927 kg/kWh	86 kg/kWh
Sulphur Dioxide (SO_2)	3,181 kg/kWh	286 kg/kWh
Oxide of Nitrogen (NOx)	1,744 kg/kWh	286 kg/kWh

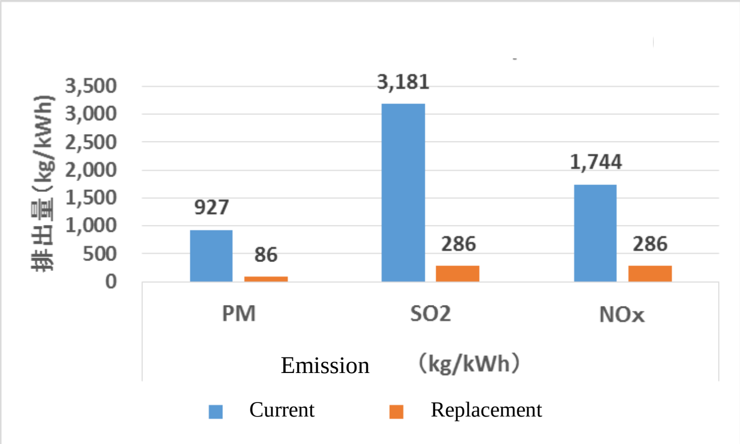


Figure 11.4-6 Reduction of pollutant matters by replacement comparison with average

Environmental measures by replacement to meet the new environmental norms is found to contribute remarkable improvement for environment.

CHAPTER 12

STEERING COMMITTEE

CHAPTER 12
STEERING COMMITTEE

This idea of the replacement of Badarpur has initially proposed in the Electricity Working Group Meeting in August, 2015. At the meeting, although an issue of chimney height is mentioned, this was recognized as one of India-Japan bilateral cooperation in power sector.

This feasibility study is initially conducted for joint feasibility study of the replacement of NTPC owned Badarpur TPS to latest USC. In case that this feasibility study materialized, international competitive tender by NTPC is conducted. To participate this tender, consortium by Japanese manufacturers will be considered. Steering committee Steering committee members from CEA (1), NTPC (4) from India side, Study team (JPOWER (2), Kyusyu (2) and JCOAL (1)) from Japanese side are nominated to discuss the progress of the studies under supervision by both governments.

12.1 1st Steering committee in Delhi

1st Steering committee has been held on January 11, 2016 at NTPC Badarpur TPS to discuss a result obtained in 1st site survey and finalization of detailed study case out of following cases.

Case1: 2 × 660 MW at ash dyke area

Case2: demolition of current 3 × 95 MW unit, construction of 1 × 660 MW, demolition of current 2 × 210 MW, construction of 1 × 660 MW

Case3: demolition of current unit, construction of 2 × 660 MW at current area

Case1 is selected as further detailed study. Regarding the chimney height, 150 m, as high as current chimney is selected for further study such as environmental impact simulation.

12.2 2nd Steering committee

2nd Steering committee has been planned in Japan during Observation of ISOGO TPS which is a model plant of the feasibility study. MOP intimated in the previous week of the 2nd steering committee that in principal, the replacement of Badarpur is not implemented with economical reason of generation cost, not with environmental reason. I this connection, 2nd steering committee has been canceled.

12.3 Debriefing Meeting

12.3.1 Debriefing Meeting

Debriefing meeting has been held at NTPC SCOPE Complex on June 14, 2016 to participate all concerned members in both India and Japan side. Presentation of final result of the feasibility study has been presented by the study team and discussion took place. Overall result is accepted by NTPC and some of the detailed requests are presented. Final report will be submitted to consider the discussion in this debriefing meeting.

12.3.2 Issues to be addressed if in the case that replacement of Badarpur is implemented

(1) Chimney height

According to the minutes of Electricity Working Group of 8th India-Japan Energy Dialogue on August 25, 2015, chimney height is described as "Presentation on Badarpur Power Station (proposed feasibility study by JCOAL covered under the third CEA-JCOAL MoU of executing a replacement project in Badarpur TPS similar to the Japanese experience at the Isogo Thermal Power Station) was made by Japanese side. NTPC informed that results of this study will be beneficial. However, chimney height restriction at Badarpur needs to be kept in mind while conducting the study."

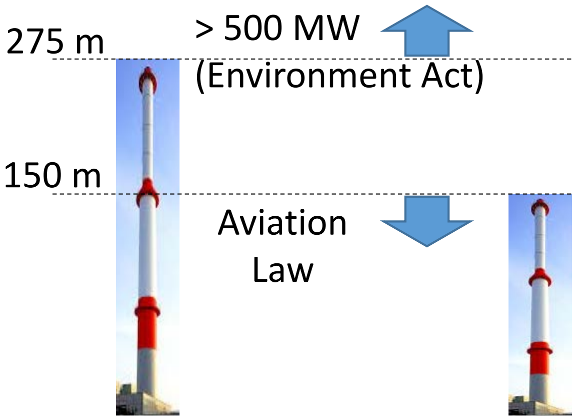


Figure 12.3-1 Chimney height, Environment Act and aviation law

Stack height of new plant is designed 150 m which is the same as current height considering the air quality value simulation as well as aviation law (Figure 12.3-1).

In the current Act, chimney height of 500 MW over plant should be kept as 275 m, but scientifically, it is much safer if concentration of NOx, SOx at chimney exit point is low enough even height is not higher than 275 m.

Further discussion based on this result at high political level is recommended as "exceptional case with scientifically approved".

CHAPTER 13

CONCLUSION

CHAPTER 13
CONCLUSION

13.1 Conclusion of this feasibility study

Government of India introduced new environmental norms for new and all existing thermal power station (TPS) in December 2015. Power sector's current top concern is how to address the new norms for achieving higher thermal efficiency of TPS and mitigating environmental impacts. In this point of view, NTPC's Badarpur TPS has been selected as a model site, where feasibility is studied on adopting the latest USC technologies to the existing TPS along with the comprehensive environmental measures.

In the study, empowering, technical specification, construction schedule, economic feasibility GHG reduction and mitigation of environmental impact by replacement have been considered. This Japanese technologies based study will provide a good example for future new power project as well as making concrete replacement plan

Study Items are conceptual design, O&M plan, construction cost, financial analysis, environmental and social considerations, business plan, project plan, ash utilization, CO_2 reduction, project structure and steering committee. Site survey and technical meetings with Badarpur TPS have been conducted to complete above study items.

Size of new USC unit is 660 MW, its steam pressure, main steam temperature and reheat steam temperature are 26.48 MPa, 600 deg C and 600 deg C, respectively. In a turbine island, optimization of steam flow on turbine blade, long turbine blade at the last stage, and high performance seal technology are adopted.

As latest environmental technologies, low-low temperature ESP, SCR and wet limestone-gypsum FGD are selected. By adopting these new technologies, emission of new plant is kept low enough, such as 30 mg/m^3N SPM, 100 mg/m^3N NOx, 100 mg/m^3N SO_2. Diffusion simulation of these pollutant materials is also conducted and confirmed that surrounded ambient environment is kept clean. Plant water consumption is lower than 2.5 m^3/MWh to meet new norms.

Capital cost of new plant is estimated as 1,210 USD/kW, (without environmental facilities: 1,049 USD/kW) with construction period of 5 years.

CO_2 reduction effect was studied by comparing several baseline of efficiency guideline (SC), emission coefficient of grid, PAT target and current TPS emission. Annual emission reduction was 10 - 20% from each baseline. Ash demand in Delhi region is found to be very high in construction industries such as cement and blocks. As for future viding, participation by the consortium of Japanese manufactures are most considerable.

13.2 Way to the implementation

Because of the postpone of the replacement implementation at Badarpur TPS, only 1st steering committee has been held and the main purpose of this FS is changed as “to apply this result for future new project / replacement project”. In view of the comment by NTPC board member, this feasibility study was thought to show a good outcome for future opportunities.

In the debriefing meeting NTPC mentioned that this feasibility study was much beneficial for them to apply to other thermal power stations which their replacement is under consideration. In this point of view the purpose of the study could show an outcome to India power sector and need to continue an effort to be materialize a replacement.

Actually, Thermal power Station that NTPC mentioned to apply this study is Talcher (60 MW × 4, 110 MW × 2) in Odisha. This TPS is initially operated by state electricity board and transferred to NTPC its operation in 1995. So far NTPC planned to replace this TPS to 660 × 2 USC unit.

This study result is thought to be much beneficial to not only NPC but also State utilities and private sector. In this connection, dissemination of the study result in many occasion such as seminar and/or workshops very important for future materialization.

रजिस्ट्री सं॰ डी॰ एल॰-33004/99 REGD. NO. D. L.-33004/99

भारत का राजपत्र
The Gazette of India

असाधारण
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भाग III—खण्ड 4
PART III—Section 4
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सं. 217] नई दिल्ली, बुधवार, नवम्बर 18, 2009/कार्तिक 27, 1931
No. 217] NEW DELHI, WEDNESDAY, NOVEMBER 18, 2009/KARTIKA 27, 1931

राष्ट्रीय परिवेशी वायु गुणवत्ता मानक

केन्द्रीय प्रदूषण नियंत्रण बोर्ड

अधिसूचना

नई दिल्ली, 18 नवम्बर, 2009

सं. बी-29016/20/90/पी.सी.आई.-I.—वायु (प्रदूषण निवारण एवं नियंत्रण) अधिनियम, 1981 (1981 का 14) की धारा 16 की उपधारा (2) (एच) द्वारा प्रदत्त शक्तियों का प्रयोग करते हुए तथा अधिसूचना संख्या का.आ. 384(ई), दिनांक 11 अप्रैल, 1994 और का.आ. 935 (ई) दिनांक 14 अक्तूबर, 1998 के अधिक्रमण में केन्द्रीय प्रदूषण नियंत्रण बोर्ड इसके द्वारा तत्काल प्रभाव से राष्ट्रीय परिवेशी वायु गुणवत्ता मानक अधिसूचित करता है, जो इस प्रकार है:-

राष्ट्रीय परिवेशी वायु गुणवत्ता मानक

क्र. सं.	प्रदूषक	समय आधारित औसत	परिवेशी वायु में सान्द्रण		
			औद्योगिक, रिहायशी, ग्रामीण और अन्य क्षेत्र	पारिस्थितिकीय संवेदनशील क्षेत्र (केन्द्र सरकार द्वारा अधिसूचित)	प्रबोधन की पद्धति
(1)	(2)	(3)	(4)	(5)	(6)
1	सल्फर डाई आक्साइड (SO_2), µg/m^3	वार्षिक* 24 घंटे**	50 80	20 80	-उन्नत वेस्ट और गाईक -पराबैंगनी परिदीप्ती
2	नाइट्रोजन डाई आक्साइड (NO_2), µg/m^3	वार्षिक* 24 घंटे**	40 80	30 80	-उपांतरित जैकब और हॉचाइजर (सोडियम-आर्सेनाईट) -रासायनिक संदीप्ति
3	विविक्त पदार्थ (10माइक्रान से कम आकार)या PM_{10}, µg/m^3	वार्षिक* 24 घंटे**	60 100	60 100	-हरात्मक विश्लेषण -टोयम -बीटा तनुकरण पद्धति

4187 GI/2009

4	विविक्त पदार्थ (2.5 माइक्रान से कम आकार या $PM_{2.5}$, µg/m³	वार्षिक* 24 घंटे**	40 60	40 60	-हरात्मक विश्लेषण -टोयम -बीटा तनुकरण पद्धति
5	ओजोन (O_3) µg/m³	8 घंटे** 1 घंटा**	100 180	100 180	-पराबैंगनी द्वीप्तिकाल -रासायनिक संदीप्ति -रासायनिक पद्धति
6	सीसा (Pb) µg/m³	वार्षिक* 24 घंटे**	0.50 1.0	0.50 1.0	ई.पी.एम 2000 या समरूप फिल्टर पेपर का प्रयोग करके AAS/ICP पद्धति -टेफलॉन फिल्टर पेपर का प्रयोग करते हुए ED-XRF
7	कार्बन मोनोक्साइड (CO) mg/m³	8 घंटे** 1 घंटा**	02 04	02 04	-अविपेक्षी अवरक्त (NDIR) स्पैक्ट्रम मापन
8	अमोनिया (NH_3) µg/m³	वार्षिक* 24 घंटे**	100 400	100 400	-रासायनिक संदीप्ती -इण्डोफिनॉल ब्ल्यू पद्धति
9	बैन्जीन (C_6H_6) µg/m³	वार्षिक*	05	05	- गैस क्रोमेटोग्राफी आधारित सतत् विश्लेषक -अधिशोषण तथा निशोषण के बाद गैस क्रोमेटोग्राफी
10	बैन्जो (ए) पाईरीन (BaP) केवल विविक्त कण, ng/m³	वार्षिक*	01	01	-विलायक निष्कर्षण के बाद HPLC/GC द्वारा विश्लेषण
11	आर्सेनिक (As) ng/m³	वार्षिक*	06	06	-असंवितरक अवरक्त स्पैक्ट्रामिती ई.पी.एम. 2000 या समरूप फिल्टर पेपर का प्रयोग करके ICP/AAS पद्धति
12	निकिल (Ni) ng/m³	वार्षिक*	20	20	ई.पी.एम. 2000 या समरूप फिल्टर पेपर का प्रयोग करके ICP/AAS पद्धति

* वर्ष में एक समान अतंरालों पर सप्ताह में दो बार प्रति 24 घंटे तक किसी एक स्थान विशेष पर लिये गये न्यूनतम 104 मापों का वार्षिक अंकगणीतीय औसत ।

** वर्ष में 98 प्रतिशत समय पर 24 घंटे या 8 घंटे या 1 घंटा के मानीटर मापमान, जो लागू हो , अनुपालन कये जाएंगे । दो प्रतिशत समय पर यह मापमान अधिक हो सकता है, किन्तु क्रमिक दो मानीटर करने के दिनों पर नहीं ।

टिप्पणीः

1. जब कभी और जहां भी किसी अपने-अपने प्रवर्ग के लिये दो क्रमिक प्रबोधन दिनों पर मापित मूल्य, ऊपर विनिर्दिष्ट सीमा से अधिक हो तो इसे नियमित या निरंतर प्रबोधन तथा अतिरिक्त अन्वेषण करवाने के लिये पर्याप्त कारण समझा जायेगा ।

संत प्रसाद गौतम, अध्यक्ष

[विज्ञापन-III/4/184/09/असा.]

टिप्पणीः राष्ट्रीय परिवेशी वायु गुणवत्ता मानक संबंधी अधिसूचनाएँ, केन्द्रीय प्रदूषण नियंत्रण बोर्ड द्वारा भारत के राजपत्र आसाधरण में अधिसूचना संख्या का.आ. 384 (ई), दिनांक 11 अप्रैल, 1994 एवं का. आ. 935 (ई), दिनांक 14 अक्टूबर, 1998 द्वारा प्रकाशित की गयी थी ।

NATIONAL AMBIENT AIR QUALITY STANDARDS

CENTRAL POLLUTION CONTROL BOARD

NOTIFICATION

New Delhi, the 18th November, 2009

No. B-29016/20/90/PCI-I.—In exercise of the powers conferred by Sub-section (2) (h) of section 16 of the Air (Prevention and Control of Pollution) Act, 1981 (Act No.14 of 1981), and in supersession of the Notification No(s). S.O. 384(E), dated 11th April, 1994 and S.O. 935(E), dated 14th October, 1998, the Central Pollution Control Board hereby notify the National Ambient Air Quality Standards with immediate effect, namely:-

NATIONAL AMBIENT AIR QUALITY STANDARDS

S. No.	Pollutant	Time Weighted Average	Concentration in Ambient Air		
			Industrial, Residential, Rural and Other Area	Ecologically Sensitive Area (notified by Central Government)	Methods of Measurement
(1)	(2)	(3)	(4)	(5)	(6)
1	Sulphur Dioxide (SO_2), µg/m³	Annual* 24 hours**	50 80	20 80	- Improved West and Gaeke -Ultraviolet fluorescence
2	Nitrogen Dioxide (NO_2), µg/m³	Annual* 24 hours**	40 80	30 80	- Modified Jacob & Hochheiser (Na-Arsenite) - Chemiluminescence
3	Particulate Matter (size less than 10µm) or PM_{10} µg/m³	Annual* 24 hours**	60 100	60 100	- Gravimetric - TOEM - Beta attenuation
4	Particulate Matter (size less than 2.5µm) or $PM_{2.5}$ µg/m³	Annual* 24 hours**	40 60	40 60	- Gravimetric - TOEM - Beta attenuation
5	Ozone (O_3) µg/m³	8 hours** 1 hour**	100 180	100 180	- UV photometric - Chemilminescence - Chemical Method
6	Lead (Pb) µg/m³	Annual* 24 hours**	0.50 1.0	0.50 1.0	- AAS /ICP method after sampling on EPM 2000 or equivalent filter paper - ED-XRF using Teflon filter
7	Carbon Monoxide (CO) mg/m³	8 hours** 1 hour**	02 04	02 04	- Non Dispersive Infra Red (NDIR) spectroscopy
8	Ammonia (NH_3) µg/m³	Annual* 24 hours**	100 400	100 400	-Chemiluminescence -Indophenol blue method

(1)	(2)	(3)	(4)	(5)	(6)
9	Benzene (C_6H_6) µg/m³	Annual*	05	05	- Gas chromatography based continuous analyzer - Adsorption and Desorption followed by GC analysis
10	Benzo(a)Pyrene (BaP) - particulate phase only, ng/m³	Annual*	01	01	- Solvent extraction followed by HPLC/GC analysis
11	Arsenic (As), ng/m³	Annual*	06	06	- AAS /ICP method after sampling on EPM 2000 or equivalent filter paper
12	Nickel (Ni), ng/m³	Annual*	20	20	- AAS /ICP method after sampling on EPM 2000 or equivalent filter paper

* Annual arithmetic mean of minimum 104 measurements in a year at a particular site taken twice a week 24 hourly at uniform intervals.

** 24 hourly or 08 hourly or 01 hourly monitored values, as applicable, shall be complied with 98% of the time in a year. 2% of the time, they may exceed the limits but not on two consecutive days of monitoring.

Note. — Whenever and wherever monitoring results on two consecutive days of monitoring exceed the limits specified above for the respective category, it shall be considered adequate reason to institute regular or continuous monitoring and further investigation.

SANT PRASAD GAUTAM, Chairman
[ADVT-III/4/184/09/Exty.]

Note: The notifications on National Ambient Air Quality Standards were published by the Central Pollution Control Board in the Gazette of India, Extraordinary vide notification No(s). S.O. 384(E), dated 11th April, 1994 and S.O. 935(E), dated 14th October, 1998.

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रजिस्ट्री सं० डी० एल०-33004/99 REGD. NO. D. L.-33004/99

भारत का राजपत्र
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असाधारण
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भाग II—खण्ड 3—उप-खण्ड (ii)
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सं. 2620] नई दिल्ली, मंगलवार, दिसम्बर 8, 2015/अग्रहायण 17, 1937
No. 2620] NEW DELHI, TUESDAY, DECEMBER 8, 2015/AGRAHAYANA 17, 1937

पर्यावरण, वन और जलवायु परिवर्तन मंत्रालय

अधिसूचना

नई दिल्ली, 7 दिसम्बर, 2015

का.आ. 3305(अ).— केंद्रीय सरकार, पर्यावरण (संरक्षण) अधिनियम, 1986 (1986 का 29) की धारा 6 और धारा 25 द्वारा प्रदत्त शक्तियों का प्रयोग करते हुए पर्यावरण (संरक्षण) नियम, 1986 का और संशोधन करने के लिए निम्नलिखित नियम बनाती है, अर्थात् :—

1.(1) इन नियमों का संक्षिप्त नाम पर्यावरण (संरक्षण) संशोधन नियम, 2015 है ।

(2) ये उनके राजपत्र में प्रकाशन की तारीख को प्रवृत्त होंगे ।

2. पर्यावरण (संरक्षण) नियम, 1986 की अनुसूची 1 में,—

(क) क्रम सं. 5 और उससे संबंधित प्रविष्टियों के स्थान पर निम्नलिखित क्रम सं. और प्रविष्टियां अंत:स्थापित की जाएंगी, अर्थात् :—

क्रम सं.	उद्योग	मापदंड	मानक
1	**2**	**3**	**4**
5क	**ताप विद्युत संयंत्र (जल उपभोग सीमा)**	**जल उपभोग**	I. एक बार शीतलन (ओटीसी) के माध्यम से सभी संयंत्र शीतलन टावरों (सीटी) को प्रतिष्ठापित करेंगे और अधिसूचना की तारीख से दो वर्ष की अवधि के भीतर अधिकतम 3.5m^3/MWh के विनिर्दिष्ट जल उपभोग को हासिल करेंगे ।

			II. सभी विद्यमान सीटी-आधारित संयंत्र 3.5m³/MWh इस अधिसूचना के प्रकाशन की तारीख से दो वर्ष के भीतर अधिकतम 3.5m³/MWh तक के विनिर्दिष्ट जल उपभोग को कम करेंगे। III. जनवरी, 2017 के पश्चात् प्रतिष्ठापित किए जाने वाले नए संयंत्र अधिकतम 2.5 m³/MWh तक के विनिदिष्ट जल उपभोग को पूरा करेंगे और शून्य जल दुर्व्यय को हासिल करेंगे।

(ख) क्रम सं. 25 और उससे संबंधित प्रविष्टियों के पश्चात् निम्नलिखित क्रम सं. और प्रविष्टियां रखी जाएंगी, अर्थात् :—

क्रम सं.	**उद्योग**	**मापदंड**	**मानक**
1	**2**	**3**	**4**
		विविक्त पदार्थ	100 mg/Nm³
		सल्फर डायोक्साइड(SO_2)	600 mg/Nm³ (500 मेगावाट से कम क्षमता की इकाईयों से लघु इकाईयां) 200 mg/Nm³ (500 मेगावाट और उससे अधिक क्षमता की इकाईयां)
		नाइट्रोजन के आक्साइड (NOx)	300 mg/Nm³
		पारा (Hg)	0.03 mg/Nm³ (500 मेगावाट और उससे अधिक क्षमता की इकाईयां)
		1 जनवरी, 2003 के पश्चात् 31 दिसंबर, 2016* तक प्रतिष्ठापित टीपीपी (इकाईयां)	
		विविक्त पदार्थ	50 mg/Nm³
		सल्फर डायोक्साइड (SO_2)	600 mg/Nm³ (500 मेगावाट से कम क्षमता की इकाईयों से लघु इकाईयां) 200 mg/Nm³ (500 मेगावाट और उससे अधिक क्षमता की इकाईयां)
		नाइट्रोजन के आक्साइड (NOx)	300 mg/Nm³
		पारा (Hg)	0.03 mg/Nm³
		1 जनवरी, 2017** से प्रतिष्ठापित टीपीपी (इकाईयां)	
		विविक्त पदार्थ	30 mg/Nm³
		सल्फर डायोक्साइड (SO_2)	100 mg/Nm³
		नाइट्रोजन के आक्साइड	100 mg/Nm³

		(NOx)	
		पारा (Hg)	0.03 mg/Nm^3

* टीपीपी (इकाईयां) इस अधिसूचना के प्रकाशन की तारीख से दो वर्ष के भीतर परिसीमाओं को पूरा करेंगी ।

** इसके अंतर्गत सभी टीपीपी (इकाईयां) हैं, जिन्हें पर्यावरणीय निकासी प्रदान की गई है और संनिर्माण के अधीन है ।

[फा. सं. क्यू-15017/40/2007-सीपीडब्ल्यू]

डा. राशिद हसन, सलाहकार

टिप्पण :- मूल नियम भारत के राजपत्र, असाधारण, भाग II, खंड 3, उपखंड (ii) में सं. का.आ. 844(अ) 19 नवंबर, 1986 द्वारा प्रकाशित किए गए थे और उनका पश्चातवर्ती का.आ. 433(अ) तारीख 18 अप्रैल, 1987 ; सा.का.नि 176(अ) तारीख 2 अप्रैल, 1996; सा.का.नि. 97 (अ), तारीख 18 फ़रवरी, 2009 ; सा.का.नि 149(अ) तारीख 4 मार्च, 2009 ; सा.का.नि. 543(अ) तारीख 22 जुलाई, 2009 ; सा.का.नि. 739(अ) तारीख 9 सितम्बर, 2010 ; सा.का.नि. 809(अ) तारीख 4 अक्टूबर, 2010, सा.का.नि. 215(अ) तारीख 15 मार्च, 2011 ; सा.का.नि. 221(अ) तारीख 18 मार्च, 2011 ; सा.का.नि. 354(अ) तारीख 2 मई, 2011 ; सा.का.नि. 424(अ) तारीख 1 जून, 2011 ; सा.का.नि. 446(अ) तारीख 13 जून, 2011 ; सा.का.नि. 152(अ) तारीख 16 मार्च, 2012 ; सा.का.नि. 266(अ) तारीख 30 मार्च, 2012 ; सा.का.नि. 277(अ) तारीख 31 मार्च, 2012; सा.का.नि. 820(अ) तारीख 9 नवम्बर, 2012 ; सा.का.नि. 176(अ) तारीख 18 मार्च, 2013 ; सा.का.नि. 535(अ) तारीख 7 अगस्त, 2013 ; सा.का.नि. 771(अ) तारीख 11 दिसम्बर, 2013 ; सा.का.नि. 2(अ) तारीख 2 जनवरी, 2014 ; सा.का.नि. 229(अ) तारीख 28 मार्च, 2014 ; सा.का.नि. 232(अ) तारीख 31 मार्च, 2014 ; सा.का.नि. 325(अ) तारीख 7 मई, 2014, सा.का.नि. 612(अ) तारीख 25 अगस्त, 2014 और अन्तिम संशोधन सा.का.नि. 789(अ) तारीख 11 नवम्बर, 2014 किया गया था ।

MINISTRY OF ENVIRONMENT, FOREST AND CLIMATE CHANGE

NOTIFICATION

New Delhi, the 7th December, 2015

S.O. 3305(E).— In exercise of the powers conferred by sections 6 and 25 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government hereby makes the following rules further to amend the Environment (Protection) Rules, 1986, namely:–

1. (1) These rules may be called the Environment (Protection) Amendment Rules, 2015.

(2) They shall come into force on the date of their publication in the Official Gazette.

2. In the Environment (Protection) Rules, 1986, in Schedule – I, -

(a) after serial number 5 and entries relating thereto, the following serial number and entries shall be inserted, namely:–

Sr. No.	Industry	Parameter	Standards
1	2	3	4
"5A.	**Thermal Power Plant (Water consumption limit)**	**Water consumption**	I. All plants with Once Through Cooling (OTC) shall install Cooling Tower (CT) and achieve specific water consumption upto maximum of 3.5m^3/MWh within a period

			of two years from the date of publication of this notification. **II.** All existing CT-based plants reduce specific water consumption upto maximum of 3.5m^3/MWh within a period of two years from the date of publication of this notification. **III.** New plants to be installed after 1st January, 2017 shall have to meet specific water consumption upto maximum of 2.5 m^3/MWh and achieve zero waste water discharged”;

(b) for serial number 25, and the entries related thereto, the following serial number and entries shall be substituted, namely:-

Sr. No.	**Industry**	**Parameter**	**Standards**
1	**2**	**3**	**4**
“25.	**Thermal Power Plant**	**TPPs (units) installed before 31st December, 2003***	
		Particulate Matter	100 mg/Nm^3
		Sulphur Dioxide (SO_2)	600 mg/Nm^3 (Units Smaller than 500MW capacity units) 200 mg/Nm^3 (for units having capacity of 500MW and above)
		Oxides of Nitrogen (NOx)	600 mg/Nm^3
		Mercury (Hg)	0.03 mg/Nm^3(for units having capacity of 500MW and above)
		TPPs (units) installed after 1st January,2003, upto 31st December, 2016*	
		Particulate Matter	50 mg/Nm^3
		Sulphur Dioxide (SO_2)	600 mg/Nm^3 (Units Smaller than 500MW capacity units) 200 mg/Nm^3 (for units having capacity of 500MW and above)
		Oxides of Nitrogen (NOx)	300 mg/Nm^3
		Mercury (Hg)	0.03 mg/Nm^3
		TPPs (units) to be installed from 1st January, 2017**	
		Particulate Matter	30 mg/Nm^3
		Sulphur Dioxide (SO_2)	100 mg/Nm^3
		Oxides of Nitrogen (NOx)	100 mg/Nm^3
		Mercury (Hg)	0.03 mg/Nm^3

*TPPs (units) shall meet the limits within two years from date of publication of this notification.

**Includes all the TPPs (units) which have been accorded environmental clearance and are under construction”.

[F. No. Q-15017/40/2007-CPW]

Dr. RASHID HASAN, Advisor

Note: - The principal rules were published in the Gazette of India, Extraordinary, Part II, Section 3, Sub-section (i) *vide* number S.O. 844(E), dated the 19th November, 1986 and subsequently amended *vide* the following notifications:—

S.O. 433(E), dated 18th April 1987; G.S.R. 176(E) dated 2nd April, 1996; G.S.R. 97(E), dated the 18th February, 2009; G.S.R. 149(E), dated the 4th March , 2009; G.S.R. 543(E), dated 22nd July, 2009; G.S.R. 739(E), dated the 9th September, 2010; G.S.R. 809(E), dated, the 4th October, 2010, G.S.R. 215(E), dated the 15th March, 2011; G.S.R. 221(E), dated the 18th March, 2011; G.S.R. 354(E), dated the 2nd May, 2011; G.S.R. 424(E), dated the 1st June, 2011; G.S.R. 446(E), dated the 13th June, 2011; G.S.R. 152(E), dated the 16th March, 2012; G.S.R. 266(E), dated the 30th March, 2012; and G.S.R. 277(E), dated the 31st March, 2012; and G.S.R. 820(E), dated the 9th November, 2012; G.S.R. 176(E), dated the 18th March, 2013; G.S.R. 535(E), dated the 7th August, 2013; G.S.R. 771(E), dated the 11th December, 2013; G.S.R. 2(E), dated the 2nd January, 2014; G.S.R. 229(E), dated the 28th March, 2014; G.S.R. 232(E), dated the 31st March, 2014; G.S.R. 325(E), dated the 07th May, 2014, G.S.R. 612,(E), dated the 25th August, 2014 and lastly amended vide notification G.S.R. 789(E), dated 11th November, 2014.

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